

Towards Environmentally Sound Dietary Guidelines

– Scientific Basis for Environmental Assessment of the Swedish National Food Agency's Dietary Guidelines

På väg mot miljöanpassade kostråd

– vetenskapligt underlag inför miljökonsekvensanalysen av Livsmedelsverkets kostråd

Charlotte Lagerberg Fogelberg



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Preface

This is a translation of the report “*På väg mot miljöanpassade kostråd – vetenskapligt underlag inför miljökonsekvensanalysen av Livsmedelsverkets kostråd*”, which was published in 2008 (Report 9-2008) and can be downloaded from the website of the Swedish National Food Agency (www.slv.se).

The report forms the scientific background for the development of advice and guidance on how residents in Sweden can eat in accordance with national dietary guidelines in a more environmentally sound manner. Over the past few years there have been many requests for a translated version of the report.

Since the original report was published in 2008, many new studies on the environmental impacts of different foodstuffs have been published. However, the conclusions of the original report were made on a robust level and remain valid, while some conclusions have even been strengthened by results from recent studies.

The original report by the National Food Agency was translated under the supervision of Charlotte Lagerberg Fogelberg, who is responsible for any errors or discrepancies in this translation. The Centre for Sustainable Agriculture at The Swedish University of Agricultural Sciences financed the translation.

In the original report in Swedish, Maria Berglund wrote the chapter on Meat (Chapter 6) and Pernilla Tidåker wrote the Chapter on Legumes (Chapter 5), both based on literature provided by Charlotte Lagerberg Fogelberg. Eva-Lotta Lindholm contributed to Chapters 4 and 7.

Charlotte Lagerberg Fogelberg
Uppsala, 20 July 2013

Preface to the Original Report in Swedish

This report forms the scientific basis for the work of the National Food Agency (NFA) on environmental considerations relating to the Swedish dietary guidelines. The report does not claim to be definitive, but should rather be seen as an overall review and synthesis of current knowledge.

Monika Pearson is the National Food Agency's project manager for the work on environmentally sound dietary advice. Charlotte Lagerberg Fogelberg prepared this report. Maria Berglund (Hushållningssällskapet Halland), Eva-Lotta Lindholm (SLU) and Pernilla Tidåker (Svenskt Sigill) to differing extents provided limited parts of the report.

The author wishes to thank the reference group for their valuable comments during the course of the work: Christel Cederberg (C Cederberg AB), Pia Lindeskog (KF Konsument), Anita Lundström (Naturvårdsverket) [Swedish Environmental Protection Agency], Gun Rudquist (SNF) [Swedish Society for Nature Conservation], Olof Thomsson (Östergarn Tryffel) and Friederike Ziegler (SIK) [the Swedish Institute for Food and Biotechnology].

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The author is responsible for the contents of the report. The report's conclusions cannot be cited as those of the National Food Agency.

Charlotte Lagerberg Fogelberg
Uppsala, 15 May 2008

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Glossary

Alvar	A landscape type. Alvar is formed on flat limestone rock sheets with a thin soil layer, e.g. on the island of Öland
Animal unit	A measure to compare and standardise different animals depending on their species, age and production system
Anthropogenic	Influenced by humans
Biocidal product	A chemical or biological pesticide for purposes other than for protecting plants and plant products (cf. plant protection products), e.g. fungicide, rodenticide, insecticide and bactericide.
Carbon dioxide equivalent	The amount of a greenhouse gas expressed as the quantity of carbon dioxide which gives an equal climate impact. For example 1 kg of methane is equivalent to 25 kg of carbon dioxide in a 100-year perspective.
Carcass weight	Weight of the slaughtered animal without the internal organs, for cattle also without the hide
Clamp	A form of storage of root crops where potatoes, sugar beet and suchlike are heaped up and covered with straw and soil
Crop rotation	Alternating crops of different species and growth patterns in order to reduce the risk of spread of plant diseases. The crop rotation determines the sequence in which different crops are grown in a field
Direct consumption	The total amount of foodstuffs supplied by producers to private households, restaurants and catering institutions, including household consumption by producers
Electricity mix	A country's combination of different energy sources for the production of electricity, such as wind power, nuclear power and coal power
Functional unit	The unit to which the environmental impact is related, in this report often 1 kg food. The functional unit can for example be 100 g protein or 1 000 kcal

Greenhouse gases	Gases which contribute to the greenhouse effect. Some examples of greenhouse gases are carbon dioxide, methane, nitrous oxide, fluorohydrocarbons and sulphur hexafluoride
Green manure	Crops which are cultivated only to improve the soil structure, increase the organic matter content and supply plant nutrients
GWP	Global Warming Potential, i.e. the potential climate impact of a greenhouse gas expressed as the amount of carbon dioxide which results in a similar climate impact (see carbon dioxide equivalent)
ICES	International Council of the Exploration of the Sea
In-house consumption	Household consumption by producers
IP	Integrated Production. Quality and environmental framework for the agricultural sector. Cultivation strategy where conventional and organic methods are used in an integrated manner based on the specific requirements of the crop
IPCC	Intergovernmental Panel on Climate Change. The UN's scientific climate panel which compiles and evaluates scientific information on the impact of humans on climate.
KRAV	Swedish organisation which certifies farmers and companies in processing and trade according to KRAV Standards. KRAV standards fulfil the EU standards for organic production (EC 834/2007) and are stricter in some areas, e.g. regarding animal welfare. Member of IFOAM (International Federation of Organic Agriculture Movements). Certification bodies offering KRAV certification are accredited according to ISO Guide 65/EN 45 011.
Managed natural grassland	In this report refers to the management of meadow and pasture lands in order to preserve and improve their natural and cultural values

Monoculture	Cultivation of the same crop in time or space. The term monoculture is used in a broader sense in this report. It also refers to situations where the same crop is cultivated over large areas in a region, i.e. spatial monoculture at landscape level, or when the same crop is cultivated year after year, i.e. temporal monoculture. Monocultures over time also give rise to increased monoculture at landscape level, since the pattern is not interrupted by having different crops, as in a rotation system
NNR	Nordic Nutrition Recommendations
Organic matter content	A measure of the soil's content of organic matter. Humus content.
Palm kernel expeller	A by-product of the extraction of palm kernel oil
Pesticide	Includes plant protection products and biocidal products
Plant protection products	Pesticides intended to protect plants and plant products mainly within agriculture, forestry and horticulture. Chemical plant protection products can be classified into the sub-groups weedkillers (herbicides), fungicides and insecticides
Primary energy	The sum of energy used for each energy carrier, from extraction of fuel via conversion and distribution, to one MJ of secondary energy is made available as useful or delivered energy in the form of electricity or vehicle fuel, for example. Primary energy has not been subjected to conversion but is expressed as the energy of energy carriers serving as inputs
Riksmaten	Riksmaten 1997/98 – Swedish national dietary survey on adults; Riksmaten 2003 – Swedish national dietary survey on children
Seasonally adapted consumption	In this report, seasonally adapted consumption refers to eating in accordance with the Swedish growing season and using Swedish products that store well (with little waste relative to the environmental impact of the storage process) from harvest to consumption

Secondary energy	Energy content of energy carriers which are produced through conversion of other so-called primary energy forms (see Primary energy). Electricity is one example of an energy carrier which is considered secondary energy
SNR	Swedish Nutrition Recommendations. Revised regularly, approximately every eight years. SNR is based on extensive supporting scientific data produced in collaborations between the Nordic countries.
SNÖ	Swedish Nutrition Recommendations Objectified. A report in which the National Food Agency, through a four-week menu, shows how to eat in accordance with the recommendations. This has resulted in recommended quantities of different foods
Steer	Castrated bull
Suckler cow	Cow which gives milk to her calf, but is not milked
Total consumption	The total consumption of different food raw materials by humans. This includes direct consumption of various raw foodstuffs and inputs of food raw materials and semi-processed products for further processing in the food industry
Zoonosis	Disease which can be transmitted from animals to humans. Also called zoonotic disease.

1. Sammanfattning

Livsmedelsverkets miljöarbete har tidigare fokuserat på direkt miljöpåverkan av myndighetens verksamhet, exempelvis val rörande sopsortering, uppvärmning och resor. Myndigheten har fått en annan roll sedan verket 2006 tilldelades ett särskilt sektorsansvar för miljömålsarbetet. Det innebär att myndigheten ska vara samlande och pådrivande samt stödja övriga berörda parter i det nationella arbetet för en ekologiskt hållbar utveckling. Med föreliggande utredning lägger Livsmedelsverket grunden för sitt arbete att söka miljöanpassa sina nuvarande råd och rekommendationer om kost, vilka har sin utgångspunkt i vad som är näringsriktigt.

I denna rapport diskuteras hur den svenska konsumenten kan äta inom ett urval livsmedelsgrupper på ett mer miljöanpassat sätt. Utifrån vad vi vet idag pekar utredningen på möjliga sätt att minska miljöpåverkan från konsumtionen inom de livsmedelsgrupper som behandlas. Rapporten är inte avsedd att ge slutgiltiga svar, utan lägger grunden för den fortsatta processen där kontinuerlig tillförsel av framtida kunskapsunderlag bidrar till fortsatta diskussioner och överföring till konkreta råd kring den svenska konsumentens kosthållning.

Rapporten omfattar frågor främst relaterade till fyra av de 16 nationella miljö kvalitetsmålen (Begränsad klimatpåverkan, Giftfri miljö, Ett rikt odlingslandskap och Ett rikt växt- och djurliv) samt strategin om giftfria resurssnåla kretslopp (GRK -strategin), dvs olika typer av miljöpåverkan behandlas snarare än enbart klimatrelaterade sådana. För animalieprodukter omfattas även miljö kvalitetsmålet Ingen övergödning. Beroende av hur tillgängliga studier avgränsats behandlar rapporten tillverkning av livsmedel, transporter och hantering i hushållet. Livsmedelsverket och Naturvårdsverket har prioriterat livsmedel som det är önskvärt att vi äter. Livsmedel som godis, läsk, glass, bakverk, snacks och alkoholhaltiga drycker ingår inte. Ägg ingår inte, p g a brist på kunskap/data.

För livsmedelsgruppen frukt och grönsaker vore det miljömässigt fördelaktigt att äta mer svenska äpplen och mer svenska rotfrukter (helst odlade på mineraljordar) samt färre bananer, vindruvor och citrusfrukter. Det vore önskvärt med en större andel ekologiska produkter, i synnerhet av bananer, citrus och vindruvor. Även att öka andelen förädlade produkter som producerats av råvaror från närområdet och med svensk elmix samt att undvika flygtransporterade och lastbilstransporterade produkter vore positivt. Det vore önskvärt att säsonganpassa vår konsumtion av frukt och grönsaker. Det handlar inte om att utesluta exempelvis bananer eller mango eller vinterodlade importerade salladsgrönsaker, utan om att betrakta dessa mer som lyxvaror som man toppar sin konsumtion med. Det handlar sålunda om att äta ofta och mer av produkter som har mindre miljöpåverkan samt sällan och mindre av produkter som har relativt större miljöpåverkan.

Vad gäller spannmål, ris och potatis vore det miljömässigt fördelaktigt att öka andelen lokalproducerad potatis samt att undvika torkade potatisprodukter. Även en ökad andel spannmålsprodukter från närområdet (Sverige och dess grannländer) vore bra. Det vore önskvärt att inte öka konsumtionen av ris ytterligare, utan att hellre ersätta det med oförädlade spannmålsprodukter eller potatis. Miljömässigt har ekologiska produkter en fördel i att de inte bidrar till spridning av växtskyddsmedel i ekosystemen och troligen bidrar till ökad biologisk mångfald.

En generell slutsats om miljöpåverkan från olika baljväxter är att de är mindre miljöpåverkande än kött, oavsett om de är inhemska eller importerade. En säsongsanpassad kosthållning kan vara en viktig aspekt vad gäller färska baljväxter. Långa transporter, i synnerhet flygtransporter, av färska baljväxter såsom sockerärter och haricots vore ger oproportionerligt stor miljöbelastning.

Det finns utrymme att minska köttkonsumtionen utan att ändra på nuvarande kostrekommendation. Minskad köttkonsumtion kan med lämplig prioritering och fördelning ge flera miljöfördelar. Ur miljösynpunkt och internationellt perspektiv får svensk köttproduktion stöd i litteraturen. Ett första sätt att anpassa köttkonsumtionen för att uppnå miljömålen är att minska importen av såväl kött som fodermedel. Köttimporten utgör idag omkring en tredjedel av köttkonsumtionen. En nationell produktion av nöt- och lammkött är nödvändig för att bevara betesmarkerna. Nöt- och lammkött bör i första hand vara producerat med foder från betesmarker. Det finns även flera fördelar med att välja lokalproducerat kött. Bland annat minskar det behovet av att transportera djur och foder samt gynnar en jämnare balans mellan animalieproduktion och växtodling inom det inhemska jordbruket.

För matfetter vore det miljömässigt fördelaktigt att minska användningen av palmolja till fördel för främst raps - eller i andra hand olivolja. Det är generellt önskvärt att välja ekologiska oljor och matfetter. Vad gäller smör är det ur miljösynpunkt viktigt att såväl magra som feta produkter, dvs kons hela produktion, tas tillvara.

Då buteljerat vatten är att betrakta som en lyxprodukt, som inte har någon näringsmässig fördel framför kranvatten, kan minskad användning av flaskvatten bidra positivt till GRK-strategin. Flaskvatten utgör endast en liten del av vår konsumtions samlade miljöpåverkan, men beräknas trots allt bidra med 34 000-74 000 ton koldioxidekvivalenter per år.

Utredningens slutsatser och rekommendationer kan förenklat uttryckas i nedanstående punkter:

Frukt och grönsaker

- Öka konsumtionen av frukt och grönsaker
- Anpassa konsumtionen efter svensk säsong
- Öka andelen svenska äpplen
- Öka andelen svenska rotfrukter
- Känsliga frukter och grönsaker bör tas från närområdet
- Minska konsumtionen av bananer, citrusfrukter och vindruvor

- Öka andelen ekologiskt producerade grönsaker och frukter
- Undvik produkter som transporterats med flyg och långväga lastbilstransporter

Spannmål, ris och potatis

- Använd främst inhemsk spannmål
- Öka inte riskonsumtionen
- Öka andelen potatis från närområdet

Baljväxter

- Öka mängden torkade baljväxter
- Öka andelen inhemskt odlade baljväxter

Kött och mejerivaror

- Minska köttkonsumtionen
- Öka andelen inhemsk produktion
- Öka andelen kött och mjölk som producerats med inhemskt foder
- Öka andelen betes- och grovfoderbaserad produktion av nöt och lamm
- Öka andelen naturbetesbaserad produktion inom nöt och lamm
- Öka andelen kött från kombinerad mjölk- och köttproduktion

Matfett

- Öka andelen inhemskt odlad och inhemskt förädlad rapsolja
- Minska andelen olivolja
- Minska andelen palmolja
- Öka andelen smör från mjölkcor som ätit mer inhemskt foder

Till ovanstående bör tilläggas att det för att minska miljöpåverkan från svenskens livsmedelskonsumtion är viktigt att minska svinnet främst i hushåll och storkök samt att minska transportererna längs hela livsmedelskedjan. Det är viktigt att konsumenten tillägnar sig kunskaper om hur olika livsmedel bör hanteras och förvaras för att inte förkorta hållbarheten. Vid tillagning i hemmet finns möjligheter att minska klimatpåverkan genom såväl tillagningsmetod som miljösmartare tillvägagångssätt inom tillagningsmetoder. Även andra beteenden behöver utmanas för att minska miljöpåverkan från vår livsmedelskonsumtion. För ökad effekt bör miljöanpassade kostråd därför även innehålla rekommendationer om konsumentens beteenden kring mat.

Rapporten visar också på kunskapsluckor och behov av utvecklingsarbete.

Summary

The Swedish National Food Agency (NFA) has until recently focused its environmental work on the direct environmental impact of its actions, such as on heating, waste separation and travelling. However, since 2006 the Agency has been given another role with increased sector responsibilities regarding national environmental quality objectives and is now expected to coordinate and support players at the national level to strive towards ecologically sustainable development. With this report, the Agency lays the foundations for its work on environmentally sound dietary guidelines, which is based on nutritional needs.

The report discusses how Swedish consumers can eat from several food groups in a more environmentally sound manner. Based on present knowledge, the report indicates possible ways to decrease the environmental impact from consumption within the food groups discussed. The report is not intended to provide definite solutions but rather act as the foundation for a continuing process where future knowledge adds to further discussion, generating tangible advice regarding the food habits of Swedish consumers.

The report covers topics relating primarily to four of Sweden's 16 national Environmental Quality Objectives (*Reduced Climate Impact; A Non-Toxic Environment; A Varied Agricultural Landscape; A Rich Diversity of Plant and Animal Life*) and to the national Strategy for Non-Toxic, Resource-Efficient Cyclical Systems (the GRK strategy). Overall, a number of different environmental impacts are discussed, rather than only climate-related impacts. An additional consideration was inclusion of the *Zero Eutrophication* objective for animal products.

Depending on how the studies available were delimited, the report discusses food production, transportation and handling of food in the household. The National Food Agency and the Swedish Environmental Protection Agency have prioritised those food groups that are nutritionally desirable, i.e. products such as sweets, soft drinks, ice cream, pastries, snacks and alcoholic beverages are not included. Eggs are not included due to lack of data.

Within the food group *fruit and vegetables*, it would be an environmental advantage to consume more Swedish apples and Swedish root crops (preferably grown on mineral soils), and less bananas, grapes and citrus. A larger proportion of organic products would be favourable, particularly regarding bananas, grapes and citrus. It would be advantageous to increase the proportion of processed products originating from raw materials from local areas and processed using the Swedish electricity mix, and also to avoid freight by air or lorry.

It would be environmentally favourable to adapt consumption of fruit and vegetables to the domestic growing season and using products that store well (with little waste relative to the environmental impact of the storage process) from harvest to consumption. This is not a matter of excluding for instance bananas, mangos or imported winter-grown salad vegetables, but of regarding and valuing these products as more of a luxury in the diet. It is thus a matter of eating more products with less environmental impact and eating smaller amounts, less often, of products with relatively greater environmental impact.

Regarding *cereals, rice and potatoes*, it would be environmentally beneficial to increase the proportion of locally produced potatoes and to decrease the consumption of dried potato products. An increased proportion of cereal products from Sweden and its neighbouring countries would be an advantage. It would be desirable not to increase rice consumption further but rather replace it with relatively unprocessed cereals and potatoes. From an environmental point of view, organic products have an advantage in that they do not contribute to the dispersion of pesticides in ecosystems and that they are likely to contribute to increased biodiversity.

A general conclusion regarding *legumes* is that they have less impact than meat on the environment, regardless of whether they are locally produced or imported. Seasonally based consumption could be an important aspect of fresh legumes. Long transport, especially by air, of fresh legumes such as sugar snap peas and green beans generates a disproportionately large impact on the environment.

There is scope to decrease *meat* consumption without alterations to the present dietary guidelines. Lower meat consumption with appropriate prioritisation and distribution among meat types (beef, pork, chicken, lamb) may have several environmental advantages. From an environmental and an international perspective, Swedish meat production performs well according to the literature.

As a first means to reach the Environmental Quality Objectives, meat consumption can be adjusted by lowering the imports of meat and animal feedstuffs. Meat imports currently represent about one-third of Swedish meat consumption. National production of beef and lamb is necessary for the preservation of grazing areas. Beef and lamb should primarily be produced from grazing areas. Furthermore, choosing locally produced meat carries several advantages. For instance, it reduces the need to transport animals and feedstuffs and it also favours a more even balance between animal production and crop production within the Swedish agricultural system.

Regarding *dietary fats and oils*, it would be environmentally beneficial to lower the use of palm oil in the first instance, and olive oil in the second instance, in favour of rapeseed oil. It is generally desirable to choose organic dietary fats and oils. Concerning butter, from an environmental point of view, it is important that all products from the cow are utilised, i.e. both the lean and the fatty products.

Bottled water is considered a luxury product without any nutritional advantages over tap water. Lower use of bottled water would make a positive contribution to the GRK strategy. Bottled water generates only a small part of the environmental impact from total consumption in Sweden, but nevertheless contributes 34 000-74 000 tonnes of carbon dioxide equivalents per year.

Conclusions and recommendations from the report are simplified in the following points

Fruit and vegetables

- Increase consumption of fruit and vegetables
- Adapt consumption to the Swedish season
- Increase the proportion of Swedish apples
- Increase the proportion of Swedish root vegetables
- Source perishable fruit and vegetables from relatively local and regional areas
- Reduce consumption of bananas, citrus fruits and grapes
- Increase the proportion of organically produced fruit and vegetables
- Avoid products freighted by air and long-distance truck transport

Cereals, rice and potatoes

- Use primarily domestic cereals
- Do not increase rice consumption
- Increase the proportion of potatoes from relatively local and regional areas

Legumes

- Increase the amount of dried legumes
- Increase the proportion of domestically produced legumes

Meat and meat products

- Decrease total meat consumption
- Increase the proportion of domestic products
- Increase the proportion of meat and milk produced by domestic feed
- Concerning beef and lamb: increase the proportion based on grazing and roughage
- Concerning beef and lamb: increase the proportion of natural pasture-based production
- Increase the proportion of meat from combined milk and meat production

Dietary fats and oils

- Increase the proportion of domestically produced and domestically processed rapeseed oil
- Decrease the proportion of palm oil
- Decrease the proportion of olive oil
- Concerning butter: increase the proportion of butter from cows that consume an increased proportion of domestic feed

In addition to the above, in order to decrease the environmental impact from the Swedish food consumption, it is vital to decrease food waste, particularly in

households and food service institutions, and to decrease transport along the entire food chain. It is also important that consumers acquire knowledge about how different foodstuffs should be handled and stored in order to avoid shortening the shelf-life. There are several possibilities for households to decrease their climate impact through more environmentally sound methods of food preparation, e.g. by choice of preparation method and by climate-smart behaviour within preparation methods. Other behaviours also need to be challenged to achieve a decreased environmental impact from food consumption. To increase the effect, environmentally sound dietary advice should include advice about consumer behaviours.

The report identifies areas where knowledge is lacking and where there is a need for further research.

2. Introduction

The Swedish dietary guidelines are updated on a regular basis. The National Food Agency aims to provide environmentally adapted dietary guidelines.

In Sweden, national work on ecologically sustainable development in society is conducted using the 16 national Environmental Quality Objectives decided by the Riksdag [The Swedish Parliament] (Regeringen, 1998; 2001; 2005; Figure 2.1). These objectives form the benchmarks for the work of the country's local, regional and central authorities. Another component of the sustainability work is the written communication from the Government to the parliament on the objectives for organic production and consumption (Regeringen, 2006).

- | | |
|---|--|
| 1. <i>Reduced Climate Impact</i> | 9. <i>Good-Quality Groundwater</i> |
| 2. <i>Clean Air</i> | 10. <i>A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos</i> |
| 3. <i>Natural Acidification Only</i> | 11. <i>Thriving Wetlands</i> |
| 4. <i>A Non-Toxic Environment</i> | 12. <i>Sustainable Forests</i> |
| 5. <i>A Protective Ozone Layer</i> | 13. <i>A Varied Agricultural Landscape</i> |
| 6. <i>A Safe Radiation Environment</i> | 14. <i>A Magnificent Mountain Landscape</i> |
| 7. <i>Zero Eutrophication</i> | 15. <i>A Good Built Environment</i> |
| 8. <i>Flourishing Lakes and Streams</i> | 16. <i>A Rich Diversity of Plant and Animal Life</i> |

Figure 2.1. The sixteen Swedish environmental quality objectives (Regeringen, 1998; 2001; 2005).

The starting point for the current consumer guidelines and quantities of various foods are the *Nordic Nutrition Recommendations* (NNR) (Nordiska Ministerrådet, 2004) and the report *Swedish Nutrition Recommendations Objectified* (SNÖ; Enghart Barbieri & Lindvall, 2003). The purpose of the present work was to create a scientific basis that will lay the foundation for designing environmentally sound dietary guidelines. Such environmentally sound advice is based on the same balanced nutritional content, i.e. it is intended to promote good, healthy eating habits and protect the environment.

The dietary guidelines from the National Food Agency include the majority of food groups. Five pieces of dietary guidelines are emphasised in which the National Food Agency specifies the most important dietary changes that should be made. Moreover, there is additional dietary advice on other food groups.

The five most important advice statements can be summarised as follows:

- Eat a lot of fruit and vegetables – preferably 500 g per day! It refers to three fruits and two generous servings of vegetables
- Preferably choose wholemeal when you eat bread, cereals, pasta and rice
- Preferably choose Keyhole-labeled foods!
- Eat fish often – preferably three times a week!
- Change to liquid margarine or oil when you cook!

The National Food Agency recommends the following consumption per day:

- ½ dl cooked legumes
- 1-2 portions of potato, rice or pasta
- approximately 200-250 g cereal products
- ½ l low-fat milk or equivalent
- approximately 100 g lean meat/cured meat products + 40 g meat products rich in iron

The National Food Agency has until recently focused its environmental work on the direct environmental impact of its actions, such as on heating, waste separation and travelling. However, since 2006 the Agency has been given increased responsibilities regarding environmental work. It is now required to coordinate and support players in the national arena to strive towards ecologically sustainable development (Livsmedelsverket, 2007a). In February 2007, the National Food Agency presented its first sector report on the work with the Environmental Quality Objectives. Future work will build further on previous investigations and studies on food and the environment, among others the studies *Att äta för en bättre miljö* [To Eat for a Better Environment] (Naturvårdsverket, 1997a) and *A Sustainable Food Supply Chain* (Naturvårdsverket, 1999a). A practical example is the cookbook *Mat med känsla för miljön* [Food with Feeling for the Environment], which was the result of a collaboration between the Swedish Consumer Agency, the National Food Agency and the Swedish Environmental Protection Agency, and considered health, environment and consumer aspects (Naturvårdsverket, 1999b).

In the report *Fakta om maten och miljö* [Facts about Food and the Environment] (Naturvårdsverket, 2003a), consumption trends, environmental impacts and life cycle assessments are investigated. Other studies on food and the environment have been initiated by the National Food Agency (Lagerberg, 2002; Kemi & Miljö, 2004). An important source of inspiration for the National Food Agency's work on food and the environment has been the so-called *första-steget-maten* [First Step Food] or *S.M.A.R.T.-maten* [S.M.A.R.T. Food] from the late 1990s (Dahlin & Lindeskog, 1998; 1999). Nowadays, the Agency's work is increasingly concentrated on indirect environmental impacts, for example those which depend on the Agency's guidelines and recommendations. With the present investigation the National Food Agency lays the foundations for its work on environmental adaption of its current advice, which is based on proper nutritional value.

This report discusses how the Swedish consumer can eat from several food groups in a more environmentally sound manner. Based on present knowledge, the report indicates possible ways to decrease the environmental impact from consumption within the food groups discussed. The report is not intended to provide definite solutions, but rather to lay the foundations for an ongoing process where future knowledge adds to further discussion, generating tangible advice regarding the food habits of Swedish consumers.

Food consumption must be viewed from a wider perspective in the light of current consumption trends and life patterns/behaviours in general, where various considerations, for example about which parts of our current lifestyles are more necessary than others, are allowed to play a role. We have to eat, but what needs to be investigated is what consumption should comprise, while at the same time having as little negative environmental impact as possible. Perceived conflicts between environmental objectives or consumer habits also need to be considered in a wider context in order to find reasonable solutions.

Participants in round table talks in Great Britain, arranged by the National Consumer Council and the Sustainable Development Commission with support from the Department of Environment, Food and Rural Affairs and the Department of Trade and Industry, agreed on the importance of individuals, companies and politicians working together to change consumer behaviour towards more sustainable life patterns (Stevenson & Keehn, 2006). However, those authors point out that none of these three players alone can change society and that politicians and businesses should focus on the mainstream consumer rather than relying on green consumers 'shopping' society out of its unsustainable situation. As regards the food area, they emphasise the potential role and power of public food procurement and suggest that procurement be stimulated to act in a more sustainable way, for example through locally produced products. A particularly interesting aspect of the study is that it emphasises the importance of the UK Food Standards Agency being given the mandate to develop sustainability-adjusted dietary guidelines (Stevenson & Keehn, 2006). The National Food Agency, the Swedish Environmental Protection Agency and the Swedish government, as well as the former direction of the Swedish Consumer Agency in this matter, thus have strong support in the British political initiative.

In this context it is important to remember that everything consumers do generates an environmental impact. All environmental impacts are not negative and each is dependent on both situation and location. Increased land use is often positive in Sweden, since it counteracts overgrowth of the landscape and if it occurs with grazing animals it also contributes to increased biodiversity (see for example Cederberg, 1999). However, an equivalent increase in land use in, for example, the Netherlands is often negative, because the landscape there is already open and heavily burdened by human activity. Likewise, increased land use in countries where virgin forest is felled for the production of foodstuffs intended for a large export market contributes to a large-scale negative environmental impact.

2.1 Delimitations

The purpose of this report is to create an environmental basis for the National Food Agency's further work on environmental considerations regarding its dietary guidelines based on available studies. Consequently the report does not formulate dietary advice; this will be included in the next phase of the National Food Agency's work. Reasoning and conclusions presented in the report primarily cover research and studies published during the past ten years. The report includes issues mainly relating to the four Environmental Quality Objectives listed below and the *Strategy on Non-Toxic, Resource-Efficient Cyclical Systems*, i.e. different types of environmental impacts are discussed rather than only climate-related matters. This is a major strength of the investigation, since climate issues only constitute one part of the substantially larger and more multi-faceted environmental field. The report does not purport to be exhaustive, but provides an overall picture of the current state of knowledge with the delimitations stated.

The National Food Agency and the Swedish Environmental Protection Agency jointly decided to focus the present report on the Environmental Quality Objectives *Reduced Climate Impact, A Non-Toxic Environment, A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life*. Additional Environmental Quality Objectives may be considered provided that it is obvious that dietary guidelines can contribute to reduced environmental impact. When it comes to food groups such as meat and dairy products, information related to the *Zero Eutrophication* objective is included. The environmentally sound dietary advice will also take into consideration the GRK Strategy (*Non-Toxic, Resource-Efficient Cyclical Systems*) (see Section 2.3.7). The number of available studies and the type of available information/knowledge were allowed to influence the structure of the chapters, so that they vary somewhat in structure. The Environmental Quality Objectives are interpreted from a wider perspective than the strict Swedish perspective. Consequently, the content of the respective environmental quality objectives is assessed irrespective of the country in which the environmental impact occurs.

Depending on how the available studies were delimited, the report discusses food production, transportation and handling of food in the household. The National Food Agency and the Swedish Environmental Protection Agency have prioritised food that is nutritionally beneficial to consume. Food products such as sweets, soft drinks, ice cream, pastries, snacks and alcoholic beverages are not included. Eggs are not included due to lack of data. The product group fish is analysed and reported separately (Ziegler, 2008).

Preparation of foods in the home and food service institutions is dealt with to a limited extent. Processed products (for example, breakfast cereals or cured meat products) are also considered to a small extent. The report does not deal with water use in the food chain other than indirectly through the energy use for handling of water in agriculture and processing. Furthermore, matters concerning genetically modified organisms (GMO) are not included.

Due to constraints of time and budget, it was necessary to make the abovementioned delimitations when preparing this report. As a consequence, the report leaves room for further studies within the areas that are not included.

2.2 Methodology and Concepts

In the preparation of this report, literature from the past ten years relating to food and the environment was reviewed. A major search of fifteen scientific databases, which in the first phase generated 4,000 publications, as well as searches in the publication lists of various universities, authorities and organisations, provided the basic source material. This was supplemented with suggestions from colleagues and interviews with the authors of selected publications and with experts within business sectors covered by the report. Besides this, an advisory reference group contributed suggestions on appropriate literature, as well as discussions on the design of the report.

Much of the quantitative data on climate impact discussed in the report are taken from life cycle assessments (LCA) or energy assessments. These data are supplemented with knowledge from other studies where different environment-related parameters were examined. In order to follow lines of reasoning about the origin of products, or about the design of production systems irrespective of their origin, it sometimes proved useful to handle the environmental impact of the production system separately from that of transport and the consumption phase.

Frequent reference is made in the report to case studies, i.e. studies of individual cases which are more or less representative of the foodstuffs that the individual consumer purchases. Models based on aggregations of more general theoretical and empirical data are to some extent also referred to in the report.

Due to differences in the details between case studies, the delimitations (see Section 2.2.1) or issues analysed in these the studies, quantitative discussions were on many occasions uninteresting. Furthermore, the age of the studies influenced the exact figures, because the systems sometimes have changed and thus descriptions of the systems analysed do not fully reflect the current systems. In general, it should be borne in mind that there is a dilemma in comparing studies of different ages. Actual differences can be masked by continuous efficiencies taking place in farming, for example through higher yield in relation to the quantities of inputs and through cooling agents with greater potential climate impact being phased out in recent years. However, the rate at which these improvements proceed varies in different parts of the world and thus qualitative reasoning formed an important basis for the conclusions in the report.

Factors outside the production system can also have an impact on its environmental performance and this adds to the difficulty of comparing the results of different studies. Such factors include labour market regulations of different countries regarding, for example, the provision of staff facilities. Furthermore, due to the differences between EU and KRAV (www.krav.se) rules and regulations on organic production, which influence the use of resources and land, it can be difficult to compare the estimated environmental impact based on studies

concerning different countries with a high degree of precision. In addition, the regulations surrounding conventional agriculture and food processing differ between countries and this also affects the design of systems.

Accordingly, it is important for readers and users of results from different studies to inform themselves about delimitations and allocations (distribution of resource use and environmental impact) and to analyse how consistent these are with the questions to which answers are being sought (Lagerberg, 2001).

2.2.1 Systems and Life Cycle Assessment

The real world is too complex to analyse in every detail and as a whole. In all types of studies, therefore, a piece of the real world is analysed, i.e. a window of attention or system, which is described and delimited in time and space.

In addition to the intrinsic properties of the assessment tool used (such as life cycle assessment (LCA); Lindfors et al., 1995; ISO, 2006a, b) and the quality of the data entered into the calculations, the outcome of the assessment is determined by the system boundaries defined in the individual study. The system boundaries delimit and define the system under study, for example in time, space and against other systems.

The actual effect of an environmental impact is partly dependent on the current precision of calculation models and partly on factors which are specific to the site, such as soil type, presence of nearby watercourses, groundwater level or the rain and wind conditions of the assessment year. Consequently, the life cycle assessment does not calculate the actual environmental impact, but the potential environmental impact (potential global warming, etc.).

The life cycle concept comprises a cradle-to-grave perspective. In general, extraction of raw materials (such as crude oil) for inputs (for example fertilisers, machines and buildings) to the different processes covered throughout the lifecycle are included, i.e. production of raw materials, food processing, consumption including storage and distribution, as well as transport and waste management throughout the whole life cycle. However, depending on the issue/s in focus in the respective study, the life cycle is often delimited (see the different types of LCA, below). A frequently used perspective for primary production within agriculture, including on-farm storage and processing if any, is called 'cradle-to-gate', i.e. the life cycle is followed up to when the products leave the farm (pass the farm gate).

Life cycle assessment (LCA) is a method for the environmental assessment of goods and services from a life cycle perspective. The method includes definitions of objectives and delimitations, inventory analysis, environmental impact assessment and interpretation. The use of resources is calculated. During environmental impact assessment the emissions from the studied system are sorted into different environmental impact categories (for example potential eutrophication, potential acidification, potential global warming and potential toxicity) and calculated on a common basis per category using different models.

For example, potential global warming is expressed in carbon dioxide equivalents, where the release of climate gases is weighted into this common unit. Sometimes all of the estimated environmental impacts are weighted together into a single index using models that are based on political, ethical or scientific considerations.

It is common to distinguish between two main types of life cycle assessment, one which is more of a descriptive type where the entire life cycle is assessed (called accounting LCA), and one which responds to change-oriented issues where the parts of the life cycle which are the same can be delimited (called change-oriented LCA).

Life cycle assessment provides valuable knowledge as regards establishing which phase within the system under study gives rise to the greatest potential impact on the environment. In this way, it provides guidance on the changes improvement efforts should be directed in order to achieve significant results within that system level. Where decisions are based on comparisons of studies with different conditions, this is taken into account in the interpretation, so that small differences are not over-interpreted.

LCA does not provide answers regarding which system is preferable over others, but is interpreted in a site-specific context where, for example, the local risk of leaching, the risks associated with different land use or whether large or small land use is positive in the surroundings of the system under study are considered. In decision-making, LCA or other assessments provide part of the decision support.

Information on environmental impact presented in this report was obtained via literature studies, in which the source material mainly consisted of life cycle assessments. Note, however, that the results from different life cycle assessments are seldom directly comparable. This is partly due to differences in system boundaries (the parts of the system and the processes and inputs selected for inclusion in the study), which are derived from various issues, allocation principles (decisions made on how to distribute resource inputs and environmental impact between different products that are produced or used jointly), regional differences and assumptions on how electricity, fertiliser, feed and other inputs are produced.

Different allocation principles may, for example, be used to assess how large a proportion of the environmental impact of feed production for dairy cows should be allocated to the milk and to the meat. The allocation is sometimes carried out according to price relationships between the main product (for example carrots for human consumption) and by-products (such as downgraded carrots which are instead used for animal feed). This economic allocation assigns less environmental impact to by-products than to the main product in proportion to the price relationships between them. Allocation can also be done according to physical relationships between different flows.

2.3 The Environmental Quality Objectives, the GRK Strategy, and Organic Production and Consumption

The current Environmental Quality Objectives and their connection to food are dealt with very briefly below. For further information, see for example the de Facto series which is issued annually by the Environmental Objectives Council (www.miljomal.nu) and the basis reports for the respective Environmental Quality Objectives. For a summary of agriculture's relationship to the Environmental Quality Objectives, see Nilsson (2007). The Environmental Quality Objectives have in the first instance a Swedish perspective, in other words they relate to what takes place within the borders of the country. This focus would not have been meaningful for the purposes of this report. Accordingly, the Environmental Quality Objectives considered here are interpreted from a wider perspective in that the report also assesses sound management of the environment in the countries from which Sweden imports food.

2.3.1 Reduced Climate Impact

The wording of the Environmental Quality Objective *Reduced Climate Impact* reads:

'The UN Framework Convention on Climate Change provides for the stabilization of concentrations of greenhouse gases in the atmosphere at levels which ensure that human activities do not have a harmful impact on the climate system. This goal must be achieved in such a way and at such a pace that biological diversity is preserved, food production is assured and other goals of sustainable development are not jeopardized. Sweden, together with other countries, must assume responsibility for achieving this global objective.'

(Regeringen, 1998; Livsmedelsverket, 2003b)

The *Reduced Climate Impact* objective has an interim target which states that 'Mean Swedish GHG emission levels for the period 2008-2012 must be 4 per cent lower than levels in 1990. Emissions are measured in carbon dioxide equivalents (CO₂Be) and include six greenhouse gases, in accordance with Kyoto Protocol and IPCC definitions. The interim target is to be met without compensation for carbon sink sequestration or flexible mechanisms.' (Regeringen, 2005). The greenhouse gases concerned are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), fluorohydrocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF₆).

In the calculation of potential climate impact, quantities of different climate gases are weighted to carbon dioxide equivalents (CO₂eq) in proportion to the potential effect of each on the climate. The relationship between carbon dioxide, nitrous oxide and methane is 1:298:25 in a 100-year perspective, which means that emissions of methane and nitrous oxide make a large climate impact relative to carbon dioxide emissions (Salomon et al., 2007).

Methane and nitrous oxide represent comparatively large proportions of the agricultural sector's greenhouse gas emissions, an important difference compared with other sectors of society, where carbon dioxide from fossil fuels is often completely dominant. Agriculture represents 35-40 per cent of global methane emissions and 65 per cent of global emissions of nitrous oxide. Globally, the agricultural sector's emissions of methane and nitrous oxide are predicted to increase sharply between 1990 and 2020 (USEPA, 2006). The largest increases in absolute terms will consist of nitrous oxide linked to land use, which is estimated to increase by more than 50 per cent during the period, and methane from animal digestion, which will increase by almost 40 per cent due to the rising number of animals. These emissions are estimated to increase first and foremost in China by almost 200 per cent, in Africa by almost 80 per cent, in South East Asia by almost 50 per cent and in Latin America by slightly more than 40 per cent. Latin America is projected to become the area with the highest methane emissions. In EU-25, however, USEPA (2006) estimates that methane emissions from animal husbandry will decrease due to the number of dairy cows decreasing.

Agriculture represents nearly one-fifth of Sweden's emissions of greenhouse gases (Nilsson, 2007). Methane and nitrous oxide emissions have decreased somewhat during recent years, mainly due to decreased animal production (SCB, 2007). Nitrous oxide is formed in arable land from nitrogen supplied with fertilisation, crop residues, etc. If the soil's nitrogen content increases, for example through fertilisation or nitrogen-rich crop residues being left in the field, this increases the estimated emissions of nitrous oxide (IPCC, 2006). The mechanisms behind the formation of nitrous oxide and the connections between different land conditions (for example water content, temperature, soil type, carbon and nitrogen content), climate, crops, cultivation measures and soil type are poorly known. Hence, at present nitrous oxide emissions are calculated according to a standard, irrespective of the above-mentioned components (IPCC, 2006). Nevertheless, the IPCC (2006) states that nitrous oxide emissions from the cultivation of peat soils in tropical areas are estimated to be twice as great as in temperate areas. Standard values are revised regularly, which is important to consider when comparing studies of different ages.

Animal husbandry produces (manure) as a by-product. Wise use of manure is therefore an important way to keep down the climate impact. For example, manure is an important source of nitrogen, which can replace nitrogen lost in cultivation. The nitrogen in manure originates from the feed the animal eats. Two important sources of the primary supply of nitrogen to the feed and the cultivation systems are nitrogen fixed from the atmosphere by legumes and mineral fertiliser.

The production of processed nitrogen fertilisers also releases nitrous oxide. In today's fertiliser manufacturing industry, around 7 kg of carbon dioxide equivalents per kg of nitrogen are released, but with the best possible technology emissions can be reduced to 3 kg carbon dioxide equivalents per kg nitrogen (Jenssen & Kongshaug, 2003). Yara, which supplies 65 per cent of the processed nitrogen fertilisers used in Swedish agriculture, will in early 2009 have reduced its emissions to 2.5 kg carbon dioxide equivalents per kg nitrogen (Bertilsson, 2008). The emissions associated with the production of mineral fertilisers differ considerably between different parts of the world.

Nearly all methane emissions can be traced to animal husbandry, primarily to digestion of feedstuffs by ruminants (in Sweden mainly cattle and sheep). Reduced number of cattle reduce methane emissions, while reduced nitrogen fertilisation can reduce nitrous oxide emissions.

Arable and pasture land emits carbon dioxide if the level of organic matter decreases, but sequesters carbon if the organic matter content increases. Carbon dioxide emissions from soil due to reduced organic matter content are not treated in this report due to inadequate knowledge concerning the connections between the carbon content of agricultural land and the amount of emissions. Generally, organic matter content can be maintained or increased in a cultivation system in which a lot of organic material is added to the soil (e.g. in the form of farmyard manure, compost or other organic fertilisers, or carbon-rich crop residues) or the tillage is relatively low-intensity and the land is covered for a large part of the year (for example, permanent pasture or cultivation of perennial leys for ruminants or as raw material for biogas production). Intensive tillage, large proportion of bare soil and the removal of organic material (for example if a large proportion of the crop residues is harvested) can contribute to reduced organic matter in the soil and thus to the soil becoming a net supplier of carbon dioxide. In a crop rotation, crops and measures that potentially increase or decrease the sequestration of carbon can occur, which means that one must consider the entire crop rotation in order to assess the net effects on the soil organic matter content.

As regards fisheries, which involve neither fertilisers nor land use, it is not surprising that the largest proportion of greenhouse gas emissions originates from the use of fossil fuels.

Transport can represent a significant part of the greenhouse gas emissions of a foodstuff. In general, the emissions of greenhouse gases per transported quantity of goods are greatest from aeroplanes, followed by lorries, boats and trains in decreasing order. Of the total emissions from the food chain caused by transport in Sweden, transport by lorry and car generates the largest quantities of greenhouse gases. The climate impact from rail transport depends on the electricity mix with which the train is powered, where the Swedish electricity mix compares very well from an international perspective. The Swedish electricity mix derives from a very small proportion of fossil fuels and thus generates small quantities of carbon dioxide equivalents compared with, for example, European electricity mixes. In other words, it is not only the transportation distance which determines the climate impact of transport. It is also a function of transport time, transport distance and mode of transport. The transport time becomes particularly important for products which are dependent on refrigeration or which risk large quantities of waste. Vehicle fill rate is also an important factor for the climate impact. The greater the proportion of maximum load used, the lower the emissions of greenhouse gases per quantity of product transported. In general, the closer the primary production, the greater the vehicle fill rate and thereby the lower the emissions of greenhouse gases per kg product (Nilsson & Sonesson, 2007). When the entire transport chain for food is studied, transport from store to home has the lowest vehicle fill rate (Sonesson et al., 2005).

2.3.2 A Non-Toxic Environment

The wording of the Environmental Quality Objective *A Non-Toxic Environment* reads:

‘The environment must be free from man-made or extracted compounds and metals that represent a threat to human health or biological diversity.’
(Regeringen, 1998; KemI, 2006)

The *Non-Toxic Environment* objective has nine interim targets. Agriculture and the food sector are affected mainly by interim targets concerning the phasing out of harmful substances (interim target 3), continuous reduction in health and environment risks of chemicals (interim target 4), dioxins in food (interim target 8) and cadmium (interim target 9).

Agriculture’s use of plant protection products contributes to the presence of residual substances in soil and water (Jordbruksverket & KemI, 2002; Adielsson et al., 2006).

For environment assessments (for example LCA) of the use of plant protection products, often only the quantities of active substances or the number of doses per hectare are quantified. The quantity of active substance is a very crude measure which does not consider the toxic effects of the plant protection products nor the risks resulting from their use. However, there are supporting data and methods to describe whether one crop performs better than another based on the use of plant protection products in cultivation. For this purpose the Swedish Chemicals Agency has developed risk indicators which can show trends in potential health and environmental hazards at national level and farm level (Bergkvist, 2004).

The National Food Agency routinely surveys the presence of pesticide residues in random samples of fresh, frozen and processed fruits, vegetables, cereals and cereal products. For example, the National Food Agency analysed 2 096 random samples for residues of 253 different pesticides during 2005 (Andersson et al., 2006). Methods to assess the total exposure from different sources or the cumulative effects from exposure to substances with similar effects are lacking today, but are under development. For more information about the National Food Agency’s monitoring programme and health effects of plant protection products see the Agency’s website (www.slv.se).

Current knowledge about long-term and total effects on health and environment is insufficient and needs to be developed further.

Cadmium is supplied to farmland via atmospheric deposition, phosphorus fertilisers, lime, manure which has been contaminated through feed and mineral additives containing cadmium, and sewage sludge. For further discussion regarding these sources see for example Nilsson (2007). As regards cadmium, in general the diet comprises the greatest source of cadmium, except for smokers and people who are exposed to cadmium in their work (Olsson, 2002; Nordlander et al., 2007). Three-quarters of the cadmium in foodstuffs comes from cereal

products and other vegetable products (Olsson, 2002). Meat and milk contains only small quantities of cadmium. The exception is kidney, which can contain very high concentrations compared with other foods, but represents a small cadmium contribution to the diet, since the consumption of kidney is small. Cadmium taken up in the body is concentrated in the kidneys (Olsson, 2002).

Dioxins are formed during incineration and can be supplied to agriculture via deposition of atmospheric pollutants on farmland and via contaminated inputs (for example feed materials) (Nilsson, 2007).

The advantage of plant protection products is that they can contribute to higher and stable harvest levels at relatively low cost. Sound crop rotations and mechanical (with machinery or by hand) or thermal weed control (such as weed flaming) are examples of measures which reduce dependence on pesticides. Mechanical and thermal control methods are more laborious and costly than chemical control and are often not as effective (Jordbruksverket, 2002).

In organic production chemical plant protection products are not used, which means that this form of production clearly contributes positively to the Environmental Quality Objective *A Non-toxic Environment*.

2.3.3 A Varied Agricultural Landscape

The wording of the Environmental Quality Objective *A Varied Agricultural Landscape* reads:

‘The value of the farmed landscape and agricultural land for biological production and food production must be protected, at the same time as biological diversity and cultural heritage assets are preserved and strengthened.’
(Regeringen, 1998; Jordbruksverket, 2003a; Regeringen, 2005)

The *Varied Agricultural Landscape* objective has six interim targets which focus on meadow and pasture land (interim target 1), small-scale habitats (interim target 2), culturally significant landscape features (interim target 3), plant genetic resources and indigenous breeds (interim target 4), action programmes for threatened species (interim target 5) and farm buildings of cultural heritage value (interim target 6). The interim targets under this Environmental Quality Objective to a great extent concern agriculture, with animal husbandry in several cases having a key role. The value of agricultural land for food production involves factors such as good nutritional status of the soil, organic matter content, soil texture, soil life and pollutants (Jordbruksverket, 2003a).

The *Varied Agricultural Landscape* objective cannot be met with anything other than sound management of the Swedish agricultural landscape. The Swedish Board of Agriculture (Jordbruksverket, 2003a) indicates that the closing down of farms will hamper the abilities to achieve this objective.

Varied crop rotations and a diversified landscape contribute to a number of the interim targets and decrease the need for chemical plant protection products, which also favours the *Rich Diversity of Plant and Animal Life* objective. Habitats which are under threat and totally dependent on grazing animals include forest pasture and ‘*alvar*’ in the World Heritage Site on Öland. The Swedish Board of Agriculture (Jordbruksverket, 2007a) points out that an increased proportion of organic farming, through its generally more varied design, can contribute to increased biodiversity, but that it is important that organic farming is also established in the more intensively cultivated plains districts of Sweden. This is supported for example by Bengtsson et al. (2005) and Öberg (2007), who report that organic production promotes the species richness of plants, birds, spiders and insects. For example, reduced use of imported feed and using more locally produced feed for domestic animal husbandry can contribute to the fulfilment of the *Varied Agricultural Landscape* environmental objective. Organic farming generally uses more locally produced feed. The regulations specify outdoor periods not only for cattle, but also for pigs and poultry, which further contributes to organic farming’s positive influence on this Environmental Quality Objective.

The Swedish Board of Agriculture (Jordbruksverket, 2007a) points out that the declining domestic milk production resulting in fewer grazing animals will affect the future ability to achieve the *Varied Agricultural Landscape* environmental objective. According to the Board, more uniform distribution of grazing animals between regions and grazing animals grazing on natural pastures to a greater extent instead of on cultivated leys would contribute positively to the fulfilment of this objective (Jordbruksverket, 2007a).

2.3.4 A Rich Diversity of Plant and Animal Life

The wording of the Environmental Quality Objective *A Rich Diversity of Plant and Animal Life* reads:

‘Biological diversity must be preserved and used sustainably for the benefit of present and future generations. Species habitats and ecosystems and their functions and processes must be safeguarded. Species must be able to survive in long-term viable populations with sufficient genetic variation. Finally, people must have access to a good natural and cultural environment rich in biological diversity, as a basis for health, quality of life and well-being.’
(Naturvårdsverket, 2003c; Regeringen, 2005)

The interim targets for *A Rich Diversity of Plant and Animal Life* focus on halting the loss of biodiversity, reducing the number of species under threat and ensuring that biodiversity and biological resources on land and in water are used sustainably (Jordbruksverket, 2003a). Agriculture affects all three interim targets.

A Rich Diversity of Plant and Animal Life benefits from farming practices that are careful of various species and their habitats. This Environmental Quality Objective is strongly linked to measures which also favour the Environmental Quality Objectives *A Non-Toxic Environment* and *A Varied Agricultural Landscape*. For example, this involves the reduced presence in the environment of

plant protection chemicals and their residues or increased presence of environments without large-scale monocultures, which means that organic production increases the ability to achieve this objective.

2.3.5 Zero Eutrophication

The wording of the Environmental Quality Objective *Zero Eutrophication* reads:

‘Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water.’

(Regeringen, 1998; Naturvårdsverket, 2003d)

The *Zero Eutrophication* objective has four interim targets that focus on emissions of phosphorus, nitrogen, ammonia and nitrous oxide. The link to agriculture is strong. Agriculture influences the *Zero Eutrophication* objective through its use of plant nutrients and its land use. The plant nutrients in focus are nitrogen and phosphorus, since they can lead to negative environmental impacts in the form of eutrophication and acidification (applies to ammonia). Nitrogen and phosphorus are important for agriculture’s resource management, since phosphorus is a finite resource and the production of mineral nitrogen is energy-intensive (Davis & Haglund, 1999).

Nitrogen leaching is determined by among other things soil type, winter temperature, topography, precipitation, proximity to the sea and streams, how and when tillage is carried out and the type, quantity and timing of fertilisation, with large variations between years (Nilsson, 2007). All tillage increases the risk of nitrogen leaching. Where the leaching occurs determines how much nitrogen reaches the sea. SCB (2007) refers to calculations that show that only 10-20 per cent of nitrogen leaching in the highlands of Småland reaches the sea, while the corresponding figure for Halland was 90 per cent. It is important to remember that from a wider perspective, society’s eutrophication problem cannot be solved at a field or farm level, because the amount of easily available nutrition supplied to society has a significant bearing on how large the problem becomes (Nilsson, 2007). Globally, more easily available nitrogen is emitted from fertiliser manufacture and the combustion of fossil fuels than the entire natural nitrogen fixation from all terrestrial ecosystems combined (Kaiser, 2001).

As regards the environmental objective *Zero Eutrophication*, there is a link to the *Reduced Climate Impact* objective, since IPCC (2006) estimates that high inputs of nitrogen to the soil will result in increased nitrous oxide emissions.

Phosphorus is not as prone to leaching as nitrogen, particularly as Sweden does not have a problem with soil phosphorus saturation, even in animal-dense areas. There is first and foremost a link to the Environmental Quality Objective *A Non-Toxic Environment* because of the presence of cadmium pollutants in the minerals from which phosphorus fertiliser agents in conventional farming are extracted. In addition to this, phosphorus mining has a substantial environmental impact (Nilsson, 2007).

The largest quantities of manure are produced and handled in conventional farming. In addition to this, conventional farming applies nitrogen, which is fixed industrially.

The risk of leaching is high in livestock-free organic cultivation systems which look to green manure crops for their supply of plant nutrients. When green manure crops are ploughed under, nitrogen is released and the risk of leaching is potentially high. However, such leaching can be effectively impeded through the cultivation of catch crops.

Agriculture dominates Swedish emissions of ammonia and animal manure is the primary source of these emissions.

Less intensive agriculture that manages its manure properly and minimises the inputs of soluble nitrogen can contribute particularly positively to the *Zero Eutrophication* objective on coastal, leaching-sensitive soils (Nilsson, 2007).

The advisory and information project *Focus on Nutrients* (Greppa Näringen) is based on the Swedish Environmental Quality Objectives. At the turn of 2006/2007, project members farmed 40-60 per cent of arable areas in the counties of Gotland, Kalmar, Blekinge, Skåne, Halland and Västra Götaland (Miljömålsrådet, 2007).

The Environmental Objectives Council's records show that *Focus on Nutrients* members have carried out extensive measures to reduce leaching and that the measures introduced within agriculture in general are starting to have an impact upon the fulfilment of the Environmental Objectives (Miljömålsrådet, 2007).

2.3.6 The GRK Strategy

The *Strategy for Non-Toxic, Resource-Efficient Cyclical Systems* (Naturvårdsverket, 2004), the so-called GRK Strategy, is one of three national strategies to fulfil the Environmental Quality Objectives. The GRK Strategy includes an environment-orientated product policy in which a life cycle perspective permeates the action proposals.

The measures are intended to have effects on several Environmental Quality Objectives. The strategy promotes the coordination of policies concerning waste, chemicals and products and includes measures concerning production, consumption and waste management.

The Swedish Environmental Protection Agency (Naturvårdsverket, 2004) highlights the problems surrounding the world's increasing material consumption and the importance of finding the instruments to stimulate changes in consumption patterns. These changed consumption patterns would then serve as the means to achieve the Environmental Quality Objectives.

The Environmental Quality Objectives discussed above can to varying degrees be related to the GRK Strategy. The Strategy clearly links to the *Non-Toxic Environment* objective in that it concerns issues related to the flow of toxic substances in the community and their dispersal and accumulation in food chains. The Environmental Quality Objective *Reduced Climate Impact* is also central in the GRK Strategy. Use of resources, including issues related to recycling/reuse and waste, is also covered by the Strategy.

2.3.7 Organic Production and Consumption

In the written communication from the Government '*Organic Production and Consumption – Objectives and Focus until 2010*' (Regeringen, 2006), the Swedish government sets out its assessment of objectives for organic production and the focus for the work on consumption of organic food in the public sector in the period until 2010. The government's assessment was that certified organic cultivation by the end of 2010 should amount to at least 20 per cent of Sweden's agricultural land. Furthermore, certified organic production of milk, eggs and meat from grazing animals should increase significantly. Finally, certified production of pig and poultry meat should increase substantially. In order to stimulate a positive development of the market, the communication stated that the consumption of certified organic food in the public sector should increase to comprise 25 per cent of total public consumption by 2010.

3. Fruit and vegetables

3.1 Recommendation and Consumption

The National Food Agency's advice since 1999 is that we should eat at least 500 g fruit and vegetables per day. Fruit and vegetables also include berries, juice and dried fruit, root vegetables and fresh herbs. It is advisable that half the amount consists of fruit and berries and half vegetables. Fruit in the form of fruit juice can make up 100 ml (100 g) of the 500 g of fruit and vegetables. Furthermore, half the vegetables should be 'coarse', for example root vegetables, white cabbage and broccoli. The dietary advice for fruit and vegetables today is: 'Eat a lot of fruit and vegetables – preferably 500 grams per day. It refers to three fruits and two generous servings of vegetables'.

At the latest national dietary survey of adults, *Riksmaten 1997/98* (Becker & Pearson, 2002), Swedish adults consumed approximately 350 g of fruit, vegetables, juice and root vegetables daily, potatoes not included. Women consumed almost one portion (approximately 80 g) more than men. Coarse vegetables such as root crops, white cabbage, spinach, broccoli, cauliflower and peas constituted approximately 25 g of a total of 110 g vegetables. Almost half of the vegetables consisted of lettuce, tomato and cucumber and the rest consisted of for example paprika, onion and mushroom. Consumption of the most common fruits was approximately equally divided between apple, citrus and banana and was in total approximately 100 g. The survey also showed that both women and men drank almost 100 ml juice per day (Becker & Pearson, 2002; Table 3.1).

In 2005, 70 per cent of imported fruit and berries comprised imports from the EU. In the same year, half the imported fruit and berries consisted of apples and citrus, mainly from the EU. Imported apples and pears primarily come from the Netherlands, France and Italy. Citrus is primarily imported from Spain (Jordbruksverket, 2007b).

In order to meet the National Food Agency's guidelines on fruit and vegetables, an additional two portions are lacking, in particular in the form of coarse vegetables (Table 3.1). Salad vegetables (lettuce, cucumber and tomato) at present represent nearly half the consumption of vegetables. Coarse vegetables such as root crops, white cabbage, broccoli, brussels sprouts and cauliflower comprise less than 10 per cent of fruit and vegetable consumption, but should constitute 25 per cent. The consumption of fruit, berries and juice amounts to slightly more than 200 g per day and with the addition of just less than half a portion of fruit the advice is met. Total intake of fruit and vegetables in the national dietary survey *Riksmaten* was estimated to be just over 120 kg per person and year (Becker & Pearson, 2002).

Table 3.1. Changes required in consumption in order to meet the National Food Agency's current guidelines on fruit and vegetables. Consumption is specified in g per person and day (Becker & Pearson, 2002)

Fruit and vegetables	Consumption 1997/1998	Advised consumption	Change required	Change required in everyday language
<i>Vegetables</i>	137	250	138	<i>Double the amount</i>
Coarse vegetables ¹	25	125	100	Five times the current amount
Other vegetables incl. salad vegetables ²	107	125	18	Slight increase
<i>Fruit</i>	214	250	36	<i>One half-portion more</i>
Apple, pear	41			
Citrus	32			
Banana	30			
Peach	5			
Berries	5			
Kiwi	3			
Canned fruit	2			
Other	8			
Juice	88			No more juice
Total fruit and vegetables	351	500	149	Nearly two portions more

¹ root crops, white cabbage, broccoli, brussels sprouts, cauliflower, beans, spinach, onions, mushrooms

² lettuce, tomato, cucumber, paprika

Swedish consumption of fruit and vegetables has increased markedly over the past 25 years. The total consumption of vegetables (including root vegetables, excluding potato), i.e. the total quantity of raw material in processed and unprocessed products, has increased by 74 per cent since 1980. Consumption amounted to 71 kg per person in 2005. Total consumption of fruit amounted to 100 kg per person, an increase of 20 per cent during the same period. Direct consumption of unprepared vegetables has increased by 90 per cent since 1980, to 42 kg per person in 2005, while the consumption of root crops has increased by 55 per cent, to 9.5 kg per person. Within the group fruit and berries, the sub-group bananas, melons and other fresh fruits occupies a special position, with a 150 per cent increase, from 9.2 kg per person in 1980 to 23 kg per person in 2005 (Jordbruksverket, 2007c). Only in countries where bananas are cultivated do people eat more bananas than in Sweden (Jordbruksverket, 2006a). Table 3.2 shows consumption trends and the degree of Swedish self-sufficiency for a range of vegetables and fruits.

Organic production of vegetables, including spices, comprised approximately 8 per cent (533 ha) of the total Swedish acreage of vegetables and spices in 2005 (Van der Krogt, 2007). The corresponding figure for greenhouse vegetables and fruit was 5 per cent each (Van der Krogt, 2007). Nearly all fruit and a large proportion of vegetables are imported.

Table 3.2. Direct consumption of a range of fruit and vegetables in Sweden, according to the Swedish Board of Agriculture (Jordbruksverket, 2007b; c). Only unprepared products

Fruit and vegetables	kg/person 1985	kg/person 2005	Degree of self-sufficiency 1995, %	Degree of self-sufficiency 2005, %
Banana		17.4	0	0
Cauliflower	1.1	1.1	48	52
Cucumber	3.5	4.3	65	61
Strawberry	3.7 ¹	2.4 ¹	75	68
Cabbage	5.8 ²	4.9 ²	50 ³	43 ³
Onion	4.3	6.6	51	49
Carrot	6.6	8.0	95	90
Leek	0.8	1.3	16	26
Pear	see Apple ⁴	See Apple ⁴	6.3	4
Lettuce	4.2 ⁵	5.6 ⁵	29	54
Tomato	5.4	9.8	26	18
Apple	23.4 ⁴	16.9 ⁴	18	14

¹ strawberries, raspberries, blackcurrants, blueberries, cowberries and other berries

² white cabbage, red cabbage, brussels sprouts, kale and broccoli

³ white cabbage and in the trade statistics including red cabbage

⁴ apples and pears, uncertain statistical basis, 2005 does not include in-house consumption, which is estimated at approximately 10 kg per person and year (Jordbruksverket, 2007b)

⁵ various types of lettuce, in 2005 also Chinese cabbage

3.2 General Comments

In this report, vegetables are divided into coarse vegetables (higher fibre content and lower water content) and onions, and other vegetables (lower fibre content and higher water content). Coarse vegetables and onions are cultivated outdoors, while some of the other vegetables are cultivated in the greenhouse.

Fruits are divided here into fruits that grow or can be cultivated in temperate climates, citrus fruits and tropical fruits.

In spite of the diversity of fruit and vegetables, there are a very limited number of environment-related studies available. Therefore various products are sometimes discussed here in a general way and in the light of the fact that they are cultivated and handled in similar systems.

It is worth observing that the total environmental impact of a product is sometimes influenced by market mechanisms rather than by inputs in production and processing. For example, if the market does not prefer a certain size or shape, this fraction is removed and is thus not included in the volume produced.

Consequently, the environmental impact per quantity consumed is lower if a larger number of fractions reaches the market and the consumer. For example, Lagerberg Fogelberg & Carlsson-Kanyama (2006) established for example that the Danish onion grower analysed could significantly improve the environmental result per kg of his onions if the discard of small fractions had been the same level as that of the Swedish grower. A British study of strawberry production found that

one-fifth of strawberries were rejected and regarded as waste because of the market's perception of quality (Defra, 2005). This problem is greater within the product group fruit and vegetables (fresh products) than for example cereals, rice, oil crops and dried legumes (dried products). The different requirements on staff facilities in a country also contribute to increasing the energy use and thereby the environmental impact per quantity consumed.

It is also important to remember that the variation in the use of resources and energy, and thereby the accompanying potential environmental impact, can be very large for products of a similar kind (such as between apples). This variation is probably greater within the group fruit and vegetables than within other product groups, since cultivation systems vary greatly within the same cultivation area. For example, a study of apple production in New Zealand, by Milà i Canals et al. (2006) found that the energy use per kg apples was three-fold higher in the cultivation system with the greatest energy use than in the one with the least energy use. Milà i Canals et al. (2007a) reported a seven- to eight-fold variation in energy use in cultivation of European apples. In a study of British strawberry cultivation systems, Defra (2005) found a six-fold variation in emissions of greenhouse gases (expressed as carbon dioxide equivalents) per hectare between strawberry cultivations. Major differences between cultivations within the same country have also been found for different types of lettuce production, which means that there is great potential for improvement (Milà i Canals et al., 2007b).

The influence of annual weather fluctuations on the potential environmental impact can be expected to be greater for products that are consumed fresh than for those that are stored, used or further processed in the form of seed, such as grain. This is because the parts of the plant that are consumed are directly exposed to weather and wind, which accentuates the general problem that a year with a high incidence of pests and diseases requires increased use of plant protection products in conventional production or increases the risk of large crop losses in organic production. Storage quality can decrease drastically under difficult conditions, which results in increased rejects prior to delivery to the consumer. The variation in sold product per hectare can therefore be large between years. It is difficult to define reference conditions, because the harvest statistics represent average values, which do not provide information on variation.

3.3 Reduced Climate Impact

Fruit and vegetables adversely contribute to the environmental quality objective *Reduced Climate Impact* through the use of fuels, directly in production through the operation of machinery and the heating of greenhouses and other premises, and indirectly through the production of inputs or transport. A warmer climate will result in greater emissions. The IPCC has estimated that the cultivation of organic soils in tropical areas gives rise to nitrous oxide emissions which are twice as high per unit area as those from cultivation of organic soils in temperate climates (IPCC, 2006). In addition, carbon dioxide emissions can occur from soils that are tilled and ploughed, especially in the case of vegetables grown on organic soil (Naturvårdsverket, 2003b; IPCC, 2006).

Tables 3.3 and 3.4 provide an overview of available studies on energy use and emissions of greenhouse gases associated with fruit and vegetables.

3.3.1 Coarse Vegetables and Onions

Carrots dominate Swedish consumption of root crops, comprising 8.0 of the 9.5 kg of root vegetables per person and year consumed in 2005 (Jordbruksverket 2007c, Table 3.2). Domestic carrots are usually available during 11 months of the year, with limited imports during spring and summer. Carrots are imported mainly from the Netherlands, Italy, Germany and Denmark. The Swedish climate is well-suited to the cultivation of carrots. Carrots are sown from mid-March to mid-June and harvested from early July to late October. They are stored and packed on order until they are finished in June of the following year.

A couple of studies have been conducted on Swedish carrots for fresh consumption. Cederberg et al. (2005) found that organically produced carrots gave rise to 36 g carbon dioxide equivalents per kg carrots. When transport, storage and packaging are subtracted from greenhouse gas emissions for conventional carrots as reported by Lagerberg Fogelberg & Carlsson-Kanyama (2006), the remaining climate impact is of the same order of magnitude as in Cederberg et al. (2005). An earlier study found higher values for fresh carrots (Carlsson-Kanyama, 1997; 1998b), but due to uncertainty about the basis used for calculation this study was disregarded here.

In comparison with carrots from the Netherlands (Lagerberg Fogelberg & Carlsson-Kanyama, 2006), Swedish-grown carrots are more efficient as regards greenhouse gases. This can be taken to illustrate that land is in short supply in the Netherlands, while in Sweden carrots make a positive contribution to a varied agricultural landscape by providing a break crop in areas dominated by cereals. The Dutch system uses more external inputs to increase the yield per unit cultivated area, however this increases the release of greenhouse gases per kg carrots.

The Danish Environmental Protection Agency (Miljøstyrelsen, 2006) found that storage of carrots in clamps was more energy-efficient, since it resulted in less greenhouse gas emissions than cold storage. For Swedish conditions this is only partly applicable. Carrots can probably be stored in clamps as long as the surrounding temperature is not too low, which is until November in the south of Sweden. The Danish Environmental Protection Agency study found that organically grown carrots gave rise to a larger climate impact due to the lower yield and the use of farmyard manure. However very high quantities of farmyard manure (50 ton/ha) were used in this Danish study, which contributed to the difference between the organic and the conventional system studied. In Sweden such large quantities are not used in either organic or conventional cultivation. Furthermore, in Sweden manure is often applied to the crop in the year before the carrots, in order for that crop to use the nitrogen, while the carrots primarily need the calcium and phosphorus that remains in the soil until the next year. This means that the environmental impact of the manure is divided between these crops.

Carrots and swedes are cultivated in similar systems with approximately the same number of machine passes and sprayings and the same yield levels (50-70 tonnes/ha). Consequently, they can be expected to have a similar potential environmental impact. Beetroot requires approximately the same inputs as the other root crops, but gives approximately half the yield per unit area. Therefore beetroot can be expected to have a greater potential environmental impact, expressed per kg of product, than carrot and swede.

Parsnips grown in Sweden have been shown to generate greenhouse gas emissions on the same level as carrots or possibly somewhat higher. The higher value found for conventionally grown parsnips compared with organically grown by Cederberg et al. (2005) was due to fertilisation with large quantities of slurry in the conventional system.

Cederberg et al. (2005) and Lagerberg Fogelberg & Carlsson-Kanyama (2006) reported similar greenhouse gas emissions for onions, 60 and 39 g carbon dioxide equivalents per kg onion, respectively, for the cultivation phase. The Danish Environmental Protection Agency (Miljøstyrelsen, 2006) reported significantly higher greenhouse gas emissions for Danish onions than Lagerberg Fogelberg & Carlsson-Kanyama (2006). However, the Danish model included emissions for cooling and washing. Since onions are handled dry and are not cold-stored, it is therefore likely that the study referred to onions that are processed in some way, for example peeled or chopped, in other words to products which would require both cooling and washing.

Cultivation on organic soils can give rise to substantial carbon dioxide emissions. Tidåker (2008) estimated that the carbon dioxide addition from organic soil may be in the order of 660 g carbon dioxide equivalents per kg carrots. However Tidåker (2008) emphasised that this calculation is rough and based on the Swedish Environmental Protection Agency's estimate of 7.9 tonnes per hectare carbon release from root crop production on organic soil (Naturvårdsverket, 1997b). The author further indicated that knowledge about the processes which generate greenhouse emissions from organic soils and how they are influenced by various factors such as peat quality and water quality is extremely limited. More information is needed to assess the actual emissions associated with cultivation.

3.3.2 Other Vegetables

Other vegetables contain comparatively more water and less fibre, for example lettuce, Chinese cabbage, other water-rich leaf vegetables, cucumber, tomato and paprika.

Swedish tomato consumption increased from 5.4 to 9.8 kg per person and year between 1985 and 2005 (Jordbruksverket, 2007c). The degree of self-sufficiency is 18 per cent (Jordbruksverket, 2007b) on an annual basis. The Swedish tomato season stretches from early March to late October-early November. In winter the consumption is entirely based on imports, but imported tomatoes are on the market all year round. Sweden imports tomatoes mainly from Denmark, the

Netherlands and Spain. In Spain, tomatoes for export are cultivated outdoors as well as in simple greenhouses and in more advanced systems with rockwool substrate, climate control and carbon dioxide fertilisation. In the Netherlands, Denmark and Sweden, tomatoes are grown in greenhouses that are heated primarily with fossil energy. In Sweden a conversion to renewable biofuels is taking place, with half the tomato acreage heated by biofuels in 2008. Swedish organically produced tomatoes are to a higher degree cultivated in simpler greenhouses for shorter growing periods, but in fact there is no difference in the need for a heating system for the respective growing period. In Sweden up to two per cent of the tomato acreage is cultivated without heating (Möller Nielsen, 2007). High-yielding greenhouses are dependent on heating for the control of climate, biological control and ventilation. Tomatoes are cultivated to an increasing degree in heated greenhouses in Spain, since this provides an opportunity to avoid frost damage and to control the climate, so that it becomes possible to decrease the use of chemical plant protection products. Opportunities to control the climate in the greenhouse allow disease and pests to be discouraged and crop growth and biological control promoted. The greenhouse also provides the possibility to produce greater quantities of food on a smaller area and in a shorter time, which can be an advantage in areas where the arable land needs to be used for cultivation of other foodstuffs, fibre raw materials or fuel crops.

Because there are so few studies of greenhouse-grown products, tomatoes in part serve as a model here for other greenhouse vegetables.

Two studies of Danish conventional tomato cultivation showed similar emissions of greenhouse gases, 3400 g (Miljøstyrelsen, 2006) and 3600 g (Lagerberg Fogelberg & Carlsson-Kanyama, 2006) carbon dioxide equivalents per kg tomato, respectively. The Danish Environmental Protection Agency (Miljøstyrelsen, 2006) reported that the figure for organic tomatoes was 40 per cent higher than the equivalent figure for conventionally cultivated tomatoes, which was explained by the lower yield. An older study showed greater potential greenhouse gas emissions for conventional tomatoes (Carlsson-Kanyama, 1997; 1998b), but in light of the huge changes that have taken place in greenhouse cultivation and the unclear basis for calculation, this older study is disregarded here. For all Swedish tomatoes, newer calculations (Lagerberg Fogelberg & Carlsson-Kanyama, 2006) indicate significantly lower emissions of greenhouse gases than in the older study.

Möller Nielsen (2007) presented weighted figures of greenhouse gas emissions from the heating of the entire Swedish tomato acreage. Due to the ongoing conversion to energy from renewable fuels within Swedish greenhouses, emissions from heating in 2007 had dropped to 1300 g carbon dioxide equivalents per kg tomatoes. However, this did not include electricity and energy for extraction, production and handling of the fuels, which means that greenhouse gas emissions were underestimated in relation to the studies cited above. The study by Möller Nielsen (2007) demonstrates the potential of changing the fuel source and increasing the efficiency of energy use. In 2007, 32 per cent of the Swedish tomato acreage was heated with biofuels and in 2008 an estimated 57 per cent of the acreage was converted to biofuels (Möller Nielsen, 2007). It is worth noting that Sweden's second largest tomato greenhouse is heated with waste heat, which does not produce any additional greenhouse effect (Myrsten, 2007). Swedish

organic tomatoes are grown in simpler greenhouses than conventional tomatoes because those farmers most often do not specialise in tomato cultivation, but have mixed production enterprises. In these simpler greenhouses, it does not pay to heat the greenhouse during the coldest months, so the growing season is approximately three months shorter and requires less energy. In smaller cultivations cold greenhouses also exist, where the greenhouse is not heated. Growing in cold greenhouses releases substantially smaller quantities of greenhouse gases. The outcome for organic and for conventional tomatoes depends on the relationship to yield. Williams et al. (2006) concluded that cultivation during a shorter season would reduce the dependence on fossil fuels (which dominates British tomato cultivation) and result in significantly reduced emissions of climate gases. Tomato production would be more seasonal in that case.

Williams et al. (2006) reported emissions of greenhouse gases of 5900 g carbon dioxide equivalents per kg British-produced classic loose tomatoes. For vine tomatoes, cherry tomatoes and vine cherry tomatoes, the corresponding emissions were more than twofold, twofold and fivefold larger, respectively, compared with the classic loose tomatoes. This was due to the lower yield of the specialist tomatoes, as the inputs were approximately the same per unit area of tomato cultivation regardless of the yield level. This means that the environmental impact per kg tomatoes is strongly linked to yield. For Swedish-grown tomatoes the differences are significantly less than those cited above, since the differences in yield between the tomato types are smaller. While the British model use the ratios 1:2.4:2:4.8 for yields of classic loose tomatoes, vine tomatoes, cherry tomatoes and vine cherry tomatoes, respectively, Swedish corresponding ratios are approximately 1:1.2:2:2.3 (Christensen, 2008). The British model thus uses significantly lower yield values for specialist vine tomatoes than are found in Sweden.

Moreover, the different types of fuel used in tomato cultivation contribute to the differences in climate impact between the Swedish (Lagerberg Fogelberg & Carlsson-Kanyama, 2006) and British study (Williams et al., 2006), with the Swedish electricity mix emitting less greenhouse gases than that in Britain. The system boundaries also differ. The British study includes the greenhouse structure and substrate, while the Swedish one does not. On the other hand, rejects at packaging are not included in the British study but are in the Swedish study. The Swedish study also includes transport to the wholesaler in Sweden, while the British study does not include activities after the company/farm gate.

Antón et al. (2005) estimated that greenhouse gas emissions for tomato cultivation in cold greenhouses are as low as 82 g carbon dioxide equivalents per kg tomatoes in Spain. However, transport to the Swedish market is not included in this figure.

The Danish Environmental Protection Agency (Miljøstyrelsen, 2006) has calculated that Danish greenhouse-grown cucumbers contribute to the greenhouse effect in the same order of magnitude as Danish tomatoes. Finnish cucumbers contribute an estimated 2300 g carbon dioxide equivalents per kg cucumbers for short cultures of 4-6 months, while year-round cultivation gives rise to 4650 g carbon dioxide equivalents per kg cucumbers (Katajajuuri, 2007). Finnish year-round cultivation of cucumbers (and tomatoes) uses a lot of artificial lighting,

which probably contributes to the large difference. In Sweden tomatoes and cucumbers are not cultivated year-round and the long cultures are about 9.5 months, which means less energy use and climate impact for these Swedish cultures. Swedish cucumber cultivation uses less energy or the same amount of energy per unit area as tomato cultivation while the yield is higher, which probably gives a slightly lower climate impact for cucumbers than for tomatoes (Christensen, 2008; Säll, 2008). Note that wrapping (with shrink film) of cucumbers is not included in that estimate.

As regards outdoor lettuce, the Swedish degree of self-sufficiency is zero during the winter, since lettuce cannot be stored. In Sweden, iceberg lettuce is cultivated outdoors, head lettuce outdoors and in simple greenhouses and pot lettuce in greenhouses. The same applies to northern Europe and Great Britain. In southern Europe lettuce is more often cultivated outdoors and in simple greenhouses. Wallén & Mattson (2002) showed that the potential contribution to climate impact for 1 kg lettuce in the consumer's household was 511 g carbon dioxide equivalents, of which almost half came from cultivation and just over a quarter from packaging. Milà i Canals et al. (2007b) compared domestic British cultivation during different times of the year to delivery to regional distribution centres for a mixture of cos lettuce, iceberg lettuce, oakleaf lettuce and chicory lettuce. Note that packaging, which made an important contribution to the climate impact of Swedish lettuce, was not included in the British study. Summer cultivation of British lettuce (May-July) produced an 80 per cent greater climate impact than autumn cultivation (July-October). Greenhouse growing during the winter produced a 3- to 16-fold greater climate impact. The authors also compared their values with cultivation in Spain and found that Spanish lettuce transported to Great Britain produced greenhouse gas emissions of the same order of magnitude as the domestically produced lettuce.

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3.3.3 Fruit and Berries Grown in Temperate Climates

Fruits such as apples, pears, cherries, plums, currants, strawberries and raspberries thrive in the Swedish climate. Melons can also be cultivated in simple tunnel greenhouses in Sweden. In addition, the forests and moors provide wild berries such as cowberries, blueberries and cloudberries. Southern and eastern Europe are among the temperate climate zones where fruits such as nectarines, peaches, citrus fruits and melons can be cultivated. Table 3.4 shows studies in which energy use and/or climate gas emissions were calculated for various fruits.

Domestic production of apples is today about the same as in 1995, but imports increased by approximately 30 per cent between 1995 and 2005 (Jordbruksverket, 2007b). Swedish apples at present are on the market a little into February. Sweden imports apples from European countries such as the Netherlands, France and Italy, but also from South America, for example from Argentina, as well as from Asia, New Zealand and the USA.

Stadig (1997) showed in a life cycle assessment of apples from Sweden, France and New Zealand that transport for the latter two made an overwhelming contribution to the climate impact. Thus while the total climate impact for the Swedish apples was around 70 g carbon dioxide equivalents per kg apples, of which half was for the cultivation phase, the corresponding figures for the French and New Zealand apples amounted to 260 (of which cultivation 47) and 520 (of which cultivation 32) g carbon dioxide equivalents per kg apples (Table 3.4). Despite the transport of apples from France being mainly carried out by truck, the French apples generated less climate impact than those from New Zealand. Stadig (1997) established that even with a storage time of 105 days, the climate impact of Swedish apples was the lowest. Despite the fact that more inputs were included in calculations by Milà i Canals (2003) and Milà i Canals et al. (2006) of the climate impact from cultivation of New Zealand apples in integrated production and organic production, the results were still of approximately the same order of magnitude as those reported by Stadig (1997) for conventional production. However, the phasing out of aggressive coolants and the modernisation of cultivation in recent years, as well as the updating of the IPCC conversion factors, would probably decrease the Stadig (1997) numbers somewhat.

Milà i Canals (2003) and Milà i Canals et al. (2006) also showed large variation between cultivations, which means that the slightly higher energy use and thereby accompanying release of greenhouse gases which can be seen for the organic production is not statistically confirmed. Those authors found that the manufacture of machines and plant protection products sometimes accounts for as much as one-quarter of the energy use in New Zealand apple cultivation. The highest energy use was found in cultivations where hydraulic ladders/platforms were widely used. In Swedish apple cultivation such equipment is not needed, because the trees are pruned into such a shape that apples can be picked without ladders.

Milà i Canals et al. (2007a) investigated the primary energy use for the supply of apples for consumption in the EU from various production areas at different consumption times during the year (Table 3.5). Note however that Swedish and Finnish conditions, with longer distances to the exporting countries and more sparsely populated consumption areas, are not included in this study. Energy use for cultivation was 0.4-3 MJ per kg apples cultivated in the country of consumption or in another European country, 0.45-0.91 MJ per kg for apples from New Zealand and 0.4-2.6 MJ per kg for apples from the southern hemisphere (except New Zealand). This is higher than in the Swedish study by Stadig (1997). The remaining energy use depends on transport and storage. Milà i Canals et al. (2007a) concluded that during the domestic season, it is advantageous from an energy point of view to consume domestic apples. During the winter, apples from the southern hemisphere have been stored for a longer time than European apples and have large storage losses, while the storage energy of European apples does not rise at such a pace that this energy use outweighs the extra energy demand per apple sold from the southern apples' waste. This means that as long as storage losses can be kept down for European apples, they should be preferred also during the winter. Milà i Canals et al. note that large variations in cultivation contribute to the difficulty in giving simple general recommendations based solely on cultivation location. Season, storage losses and mode of transport (more important for longer distances) are important in the design of recommendations. The same authors report primary energy use for apple cultivation in USA of 1.2-1.3 MJ per kg apples (Milà i Canals et al., 2007a).

Blanke & Burdick (2005) examined the impact of transport on potential climate impact and concluded that domestic (German-grown) apples stored until the middle of March require less energy than apples imported from New Zealand, which seems to partly confirm the above-mentioned results by Milà i Canals et al. (2007a). However, Blanke & Burdick (2005) used cultivation data from the 1970s and assumed the same energy use for cultivation in New Zealand and in Germany, which does not apply in today's situation. Jones (2002) reported values of the same order of magnitude as Milà i Canals et al. (2007a) for transport-related energy use for apples imported or cultivated in Great Britain and distributed via different routes. Transport energy can amount to several times the energy used in cultivation. Jones (2002) also points out that home-grown (in private gardens) apples are most often cultivated without fertilisers and plant protection products and without mechanisation, which gives virtually no energy use for the cultivation.

Reganold et al. (2001) found that organic apple production was more energy-efficient than integrated and conventional production in a four-year experimental study in a commercial apple cultivation in Yakima Valley, Washington (USA). Mouron et al. (2006) reported results for various Swiss apple cultivation systems on a per hectare basis, making it impossible to compare them with other studies reported here. However, those authors pointed to wide variations and to the importance of optimising machinery and cultivation measures, so that fuel use decreases, and of decreasing hail protection as long as yield is not affected appreciably. Hail protection is only used to a limited extent in Sweden.

The main Swedish strawberry season extends from June to July, but through the use of strawberry varieties which mature at different times and through transporting strawberries from the south and north, respectively, Swedish strawberries are available from May to August. During the summer, Sweden imports strawberries primarily from Belgium, but also from southern Europe and in the winter from Egypt, among others. A British study of strawberry cultivation (Defra, 2005; Warner, 2005; Garnett, 2006) shows a potential climate impact in the cultivation stage of approximately 400 g carbon dioxide equivalents per kg strawberries. In Sweden, strawberry cultures remain in production for several years, with the result that inputs for establishment can be allocated over several years, and they are sprayed fewer times, which suggests a lower climate impact for Swedish strawberries. The British study (Defra, 2005) made comparisons with strawberries of Spanish origin and pointed out the large, homogeneous cultivations there with limited vegetation, a lot of bare ground and large transport distances (for example 2160 km between Huelva and Dover) during which strawberries require refrigeration, which suggests a greater climate impact for Spanish strawberries than for British.

Utilising wild fruits and berries such as blueberries, cowberries and cloudberries is part of Swedish tradition and can contribute to the national food supply. Unfortunately, there are no statistics on the amount of wild berries picked in Sweden and how much could be harvested sustainably from the resources available. In addition to supplying food, berry picking provides recreation in the forest and countryside. Transport of private and commercial berry pickers and distribution over and above storage and processing contributes to the climate impact. However, berry picking can be regarded partly as recreation for private individuals, in other words the main purpose of visiting the forests and countryside is not to obtain food, which justifies allocating only a part of the transport involved to berries. Since the growth process of the berries does not require any additional inputs, it is reasonable to exploit the opportunities the forests and moors provide through berry picking. However, it is important to minimise the transport distance, so that this does not overshadow the benefit of a raw material that does not exert any extra climate impact. The growth process of berries is affected by the surrounding environment. Therefore it is important to take into account the capacity of the land to produce berries in decisions that affect the environment.

3.3.4 Citrus

Citrus fruits such as orange, grapefruit, lime, lemon, mandarin, clementine and pomelo are imported to Sweden from southern Europe, Morocco, Brazil and Israel, among others.

Oranges are imported primarily from Spain, which is the world's fourth largest orange producer. València is the Spanish region which produces the most oranges, of which approximately 70 per cent are exported. The climate impact from the integrated cultivation of oranges for fresh consumption has been shown by Sanjuán et al. (2005a) to lie in the interval 220-280 g carbon dioxide equivalents per kg oranges, which is several times greater than that for apples (Section 3.3.3).

Sanjuán et al. (2005a) analysed eight scenarios for the cultivation of oranges for fresh consumption in Valencia and investigated the significance of various cultivation measures for climate impact. The systems used very large quantities of fertiliser. Scenarios in which mineral fertilisers were supplied via the irrigation system had the greatest climate impact, which could amount to half the total climate impact. In scenarios where no tillage was carried out, the manufacture of chemical plant protection products comprised a larger share of the climate impact. Sanjuán et al. (2005b) provide no absolute data on greenhouse gas emissions from organic orange cultivation (for fresh consumption). Not surprisingly, direct fuel use represents a larger percentile share of the climate impact from organic production, while integrated cultivation is dominated by greenhouse gas emissions from mineral fertilisers which are not permitted in organic cultivation. For a comparison to be possible, the absolute emissions levels must be known for both systems.

In Brazil orange groves are most often not irrigated, while orange cultivation in Florida is a more intensive system which includes irrigation and intensive use of chemical plant protection products (Ringblom, 2004), and probably also significant quantities of mineral fertilisers. Irrigation and the use of mineral fertilisers result in increased energy use, which generates a climate impact. Coltro et al. (2006) report that increased intensification is occurring in the southern part of the state of Sao Paulo, where most Brazilian orange cultivation already occurs. Those authors also indicate that the use of mineral fertilisers is excessive and gives rise to plant nutrient leaching. Since the manufacture of nitrogen fertilisers generates greenhouse gases, this excess nitrogen fertilisation results in an unnecessary climate burden.

3.3.5 Tropical Fruits and Berries

Tropical fruits include for example banana, mango, papaya, melon and cape gooseberry. Sweden imports these fruits from various parts of the world, such as Costa Rica, Malaysia and Brazil.

Flysjö & Ohlsson (2006) found that the climate impact for melons imported from Costa Rica is significantly higher than that of the other fruit listed above (Table 3.4). Slightly more than half the climate impact derives from cultivation and one-fifth from estimated transport from the food shop to the consumer. The remaining one-fifth derives from the transport of melons between cultivation site and food shop.

Swedes eat approximately 17.5 kg bananas per person and year, the highest consumption rate of all countries except those that cultivate bananas domestically. These bananas are imported primarily from Costa Rica and Colombia, but also from Panama and Ecuador and the remaining 40 per cent from countries which cannot be identified from the statistics. Organic bananas are at present imported from for instance the Dominican Republic. Bananas are cultivated in large monocultures in which plantation life varies between 10 and 35 years depending on when problems with plant diseases, plant parasites and soil erosion become too

great. A great deal of nutrients are removed with large harvests. Conventional banana cultures can yield up to 100 tonnes bananas per ha. Since plants other than banana plants are regarded as competing for nutrients, the land is kept clear of other plants. Although some leaves are left on the ground, surface runoff from the tropical rains is very high and plant nutrient leaching is also high. The plant nutrients which are removed with harvest, leaching and soil erosion are compensated for by large doses of mineral fertilisers. In addition to aerial spraying with plant protection products cultivation measures are carried out manually (Lustig, 2004; Jordbruksverket, 2006a).

The climate impact of bananas derives primarily from the manufacture of mineral fertilisers and of plant protection products and the use of fuel associated with the aerial spraying of plant protection products, which can take place up to 60 times per year. Another addition to the contribution of bananas to climate impact is the use of plastic bags impregnated with plant protection products, which are drawn over the bunch stems to protect against damage while the bananas grow, transport of inputs and transport to the packing facility where the bananas are washed and treated with fungicides to protect them during the week-long transport to Europe (Lustig, 2004; Jordbruksverket, 2006a). When the bananas arrive at the country of consumption, they are treated with ethylene gas to start the ripening process (Jordbruksverket, 2006a).

Organic banana plantations give significantly lower yield, around half that in conventional cultivation. Because the land is not kept free of vegetation, which reduces soil erosion and surface runoff, and thereby leaching of plant nutrients, less plant nutrients need to be provided. In organic cultivation plant nutrients are supplied through farmyard manure and unprocessed mineral fertiliser, which contribute to less climate impact than for conventional cultivation. In organic cultivation only biological plant protection products are used and spraying takes place significantly fewer times, Lustig (2004) indicates 8-10 times in an example from one farm in the Dominican Republic. Climate impact therefore decreases significantly for organic cultivation of bananas (Lustig, 2004).

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3.3.6 Processed Products

There is a great shortage of studies on processed products. Table 3.4 shows a few studies on vegetables. In general, the total climate impact increases with the degree of processing as more inputs and transport of inputs are required within the longer food chain. In cases where the processing results in decreased waste and/or changes in storage and transport requirements, it is unclear what the results are calculated per unit of goods. The storage and cooking requirements associated with consumption can change with the degree of processing, but consumer behaviour in the household is poorly investigated and is not dealt with further here.

For highly processed products, the processing stage represents a large proportion of the product's total climate impact, which is related directly to the use of fossil fuels. Mattsson (1999) found that 1 kg carrot purée intended for baby food (packaged in glass jars) gave rise to nearly 1500 g carbon dioxide equivalents over the life cycle from cultivation to consumption. Of this, processing accounted for 50 per cent and packaging for 30 per cent. Lagerberg Fogelberg & Carlsson-Kanyama (2006) showed that Swedish frozen diced carrots had significantly greater potential climate impact than fresh carrots, with the processing of carrots into frozen, diced and packaged product at the wholesaler accounting for nearly three-quarters of the climate impact.

Ligthart et al. (2005a; b) estimated the effects of 600 g carrots purchased fresh, frozen and canned to be consumed boiled in the household. Fresh carrots were most energy-efficient and produced the least climate impact, frozen carrots produced just over twice the climate impact and canned carrots somewhat in between depending on how much of the can was recycled (Ligthart et al., 2005a; Foster et al., 2006). The conclusions of the study illustrate to a certain extent the problem with using percentages or proportions when comparing results. For fresh carrots, transport and particularly home transport comprised a greater percentage of the climate impact, which is not surprising since the total climate impact was so much lower than for frozen and canned carrots. Fewer per cent of a greater number, which is the case with the processed carrots, is still significant in absolute terms. Ligthart et al. (2005a, b) also established that import of products gives rise to increased climate impact. The canned carrots had lower absolute climate impact in the consumption phase than the fresh and frozen carrots. Because the frozen carrots are handled frozen, the distribution and consumption phase for these carrots contributed more to climate impact than the processing phase. For the canned carrots, packaging and the processing stage dominated the climate impact.

Angervall et al. (2006) examined the significance for frozen broccoli consumed in Sweden of being produced using Swedish-grown raw material instead of being imported as a frozen product from Spain and Ecuador. The results showed that broccoli grown and processed in Sweden would more than halve the contribution to climate impact per kg broccoli bouquets, mainly because the Swedish electricity mix generates less climate impact and because of the lower transportation requirement. The difference between frozen broccoli of Spanish or

Ecuadorian origin was negligible, with lorry transport from Spain dominating the climate impact of Spanish broccoli and mineral fertilisers dominating that of Ecuadorian broccoli.

An earlier model (Andersson, 1998), based on data from before 1994, examined tomato ketchup consumed in Sweden where the tomatoes were cultivated in Italy and tomato paste was manufactured in Italy and transported to the ketchup manufacturer in Sweden. The climate impact for this was dominated by processing and transport.

Brazil is the world's largest producer of frozen orange juice concentrate, of which 97 per cent is exported (Coltro et al., 2006). In the state of Sao Paulo alone, 400 000 people work directly in orange juice production and a further three million are indirectly dependent on this industry for their livelihood.

Schlich & Fleissner (2005; Schlich, 2005) compared the energy use of orange juice concentrate imported from Brazil to Germany with that of apple juice where the apples were cultivated in Europe or Germany and processed and packaged in Germany. Different sizes of cultivation and processing industries were examined. The study showed that juice produced from local raw material for the German market cannot automatically be assumed to be the most energy-efficient. The energy efficiency is instead determined by the type of raw material, transport distance for the raw material and distribution to the market and by the energy efficiency in processing. It is important to optimise the quantity of inputs relative to the yield, which is dependent on the organisation of the entire industrial system. Schlich & Fleissner (2005) found examples of small regional industries which performed very well energy-wise and others in which the supply of fruit raw material or distribution logistics gave rise to greater energy use for transport.

The fruit juice studies cited above have been heavily criticised by Jungbluth & Demmeler (2005) for deficiencies in methodology, calculations and selection of data. In addition to this, the global juice industry, which has high energy use per litre of juice, was excluded from the results presented in Schlich & Fleissner (2005). Jungbluth & Demmeler (2005) refer to studies which in different ways show that the variation in direct energy use or environmental impact is large between production sites, but that the relationship with production unit size is weak. The conclusion that juice produced with local raw material for the German market cannot be automatically assumed to be more or less energy-efficient however seems to hold for data presented by Jungbluth & Demmeler (2005). The fact that Sweden is more sparsely populated than Germany means that transport can be expected to have a greater influence than in other countries which have more concentrated population centres. Proximity to raw material supply and the market is thereby just as relevant for Swedish conditions.

Drying off water in order to concentrate juice requires a relatively large amount of energy, which gives rise to different climate impacts depending on the energy type used (for example natural gas and electricity) and where in the world drying takes place, in other words the climate impact of the electricity mix used. There is a lack of knowledge about how much different methods of drying and other phases in processing such as pasteurisation contribute to the climate impact. Knowledge is

also lacking regarding the climate impact associated with the storage of orange juice concentrate over the year while waiting for delivery to the customer for further processing.

Nilsson & Sonesson (2007) provide rough estimates of the climate impact for orange juice of various types and origins for the Swedish market. Owing to lorry transport through Europe, freshly squeezed juice of oranges from Spain generates a significantly greater climate impact (1770 g carbon dioxide equivalents per kg of juice) than juice from concentrate and freshly pressed orange juice from Brazilian raw ingredients (1100 and 1260 carbon dioxide equivalents per kg of juice respectively). It is unclear what is included in these calculations, for example whether storage of orange juice concentrate or transport to the shipping port is included or whether any real inventory was done. Nevertheless, this estimate confirms the significance of the mode of transport for the climate impact.

Spanish oranges for industrial purposes, such as juice production, are cultivated in southern Spain (Andalucia) on larger and more highly mechanised farms than oranges for fresh consumption (Sanjuán, 2007), see Section 3.3.4. The higher degree of mechanisation means that industrial production can be expected to have greater fuel use per hectare, which means greater potential climate impact.

Since the variation between cultivations within the same region has been shown to be great, there is also an improvement potential for processed products that could contribute to their environmental performance. Where wild berries are used as raw material much of the climate- and environment-related impact of the raw material supply is left out, provided that transport does not become too lengthy. The fact that Sweden is significantly more sparsely populated than Germany means that transport can be expected to be more prominent than reported in Schlich & Fleissner (2005) and than in other studies examining more densely populated areas. Proximity to raw material supply and the market are therefore equally relevant.

In the choice of processed products from different countries, it is important to remember that climate impact is dependent on the country's electricity mix. Processing with a cleaner electricity mix produces products with less climate impact. For example, the electricity mix in Sweden and Norway has significantly less climate impact than that in other EU countries. Provided that the raw material is produced in similar ways, processing with, for example, a southern European electricity mix consequently leads to significantly greater climate impact in comparison with the corresponding processing of locally produced raw material with the Nordic electricity mix. In addition to this, processed products often require refrigeration, meaning that the longer transportation in refrigerated lorries also affects the climate more than a product which is closer to the consumer/market.

Sun-dried products can be expected to have less climate impact than those dried with the aid of fossil fuels, provided that they have the same origin and have otherwise been treated in the same manner.

3.3.7 The Storage-Refrigeration-Transport-Waste Complex

Waste is dependent on the product's intrinsic properties and its reaction to the parameters of time, temperature and damage. Storage characteristics/conditions are of course different for different products, even apparently similar products, with for example mandarins having a shorter intrinsic shelf-life than limes. The maturation process for fruit and vegetables is also different, so that some types have a longer period when they are still tasty (such as apple, onion, root vegetables), while others deteriorate very quickly once they have reached maturity (such as mango, avocado). The risk of waste therefore becomes greater for the latter. With the aid of different storage techniques (mainly modified temperature and humidity conditions) and packaging, shelf-life can be prolonged. Milà i Canals et al. (2007a) calculated that consumer-packaged apples (four in a polystyrene tray with polythene film) required 5 MJ of primary energy per kg apples, which was more than or in the same order of magnitude as cultivation, storage and transport put together for loose apples of different origin. Provided that waste does not increase, this demonstrates a climate advantage of loose handling. Waxing after harvest can be regarded as a kind of packaging. Waxing is carried out mainly on citrus and apples, but not on Swedish products.

Skin thickness, water content and any cavities (for example papaya and peppers) affect how susceptible fruit and vegetables are to pressure and bruising. Harder fruits (for example apple) and vegetables (for example carrots) have longer intrinsic storability than softer fruits (papaya, strawberry) and vegetables (lettuce, cucumber, avocado). Chinese cabbage can be stored well into the winter, unlike lettuce. Bananas have a short shelf-life once ripening has been initiated with ethylene (Jordbruksverket, 2006a). Ready-cut chilled lettuce mixtures require continuous refrigeration so as not to deteriorate very quickly.

Storage and transportation at room temperature have of course less climate impact than storage and transportation in a refined climate. Fruit can be stored at room temperature in the household to a greater extent than vegetables. In addition to this, fruit is often consumed without cooking by heat treatment. Highly processed products often require cold storage and require cooking more often than unprocessed foods, which can be eaten fresh. Dried products take up less space in storage and transportation and can be stored and transported without climate control/at room temperature.

According to Billiard & Viard (2002), more than half the food in shops in industrialised countries is sold chilled or frozen. This reflects continuous temperature regulation from production via storage and transport to sale, which globally and generally is important from a food safety point of view.

The climate impact associated with refrigeration and freezer storage primarily derives from the use of fuel or electricity for the operation of the equipment and the use of cooling media. Note that the electricity mix in the region in which stationary storage takes place affects comparisons between different alternatives, with Swedish electricity production having a comparatively low climate impact.

The climate impact of transport is dependent on how much fuel is used, which is a function of the transportation distance, the time any refrigeration/freezing equipment needs to work and how often (also when the vehicle is standing still) and the type of fuel and infrastructure system used. Type of fuel and of infrastructure (including the vehicle) are determined by the mode of transport, mainly train, lorry and ships of various kinds. Vehicle fill rate (including return trips) and fuel efficiency are other key factors. Transportation time is determined by the transportation distance, vehicle speed and the length of stationary periods, for example breaks and rest periods, transit at borders and loading/unloading and storage of containers.

Foster et al. (2006) refer to a forthcoming study (Ritchie) in which energy use for stationary storage of fresh products in refrigerator or preservation is at the same levels, while freezer storage has significantly higher energy use. However, nothing is said about the time perspective in which the storage methods were studied, the products studied and whether packaging is included or solely maintenance energy for the storage itself, information which is essential to the results.

Stationary storage of frozen food requires more electricity than stationary storage of chilled food, which results in an overall greater total climate impact for frozen food. Chilled food requires relatively more energy to store it than to cool it to the storage temperature. Freezing, on the other hand, represents a large proportion of the energy for freezer storage. Provided that it does not entail increased demand for new infrastructure for chilled food, a shift from frozen to chilled products therefore may contribute to reduced climate impact. (Garnett, 2006)

Mobile installations are considerably less energy-efficient than stationary storage facilities. This is because the mobile units are smaller and thus have a larger surface in relation to volume and are less well insulated, so that they leak more cooling to the surrounding environment. In general, more energy is required to keep the temperature of both stationary and mobile chiller and freezer equipment low in warmer surroundings (such as tropical countries) than in colder climates (such as the Nordic countries).

Foods that are transported chilled have been shown to have greater climate impact than those that are transported in frozen form. This is because chilled fruit and vegetables require a uniform specific temperature and thereby more air circulation to distribute the chilling effect, which is more energy-demanding than maintaining a threshold temperature for frozen products. In addition, frozen products have higher density, in other words more food can be transported in the same vehicle space. (Garnett, 2006)

For coarser field-grown vegetables, where the release of greenhouse gases from the cultivation phase is relatively low, transport distance has a greater impact on the total climate impact per quantity of product than for other products with higher total climate impact per quantity of product, where the emissions from cultivation and processing dominate the life cycle. This is more pronounced for products that are transported chilled.

Milá i Canals et al. (2007a) show the significance of cooking in the home, using an example where the cooking of an apple pie with 1 kg apples requires 5 MJ primary energy. This energy use is of the same order of magnitude as that of the entire supply chain (see the example with packaged apples above). Compared with a ready-cooked, imported apple pie, the resulting climate impact is not clearcut, since the Swedish electricity mix has a low climate impact in an international perspective and the ready cooked apple pie would require refrigerated transport, probably by truck.

Processed products are offered for sale to a great extent in open cabinets or refrigerated counters that leak cooling to the surroundings, while unprocessed fruits and vegetables are not sold chilled to the same extent. There is thus a need for comparative studies which take various parameters and the actual conditions of temperature, transport and storage in food chains into consideration. Garnett (2006) reported that refrigerated storage in shops and in the home has great significance and that knowledge is lacking.

It has been shown above that transport has a large impact on the choice of the least climate-negative alternative of frozen broccoli bouquets (Section 3.3.6). For storage of apples, Stadig (1997) showed that a longer storage time of 7.5 months contributed negligibly to climate impact in comparison with one month of storage (Section 3.3.3).

Garnett (2006) highlights another interesting perspective concerning the connection between storage in the home and consumption of chilled and frozen products. Having an empty refrigerator and freezer of a certain volume in the household uses nearly as much energy as when they are partly or completely full, although the number of times the refrigerator/freezer door is opened affects the energy use. However, if consumption is changed towards more chilled and frozen products, as has happened in recent decades, the household requires larger refrigerator/freezer capacity, which increases the climate impact. In addition to this, adaptation of the infrastructure to handle these chilled and frozen products upstream in the food chain to the manufacturer has increased the overall climate impact. Were people instead to reduce their consumption of frozen and chilled products, they could use smaller refrigerators and freezers in the household and reduce the refrigerator/freezer capacity required in the earlier stages of the food chain. Garnett (2006)

Just as earlier in the chain, it is important to handle fruit and vegetables so that they are not bruised or damaged during storage, in the supermarket or during final transport and handling in the home. Damage reduces the storability and provides entry points for storage diseases and deterioration in taste and appearance. An important consequence of damage is increased waste in the form of rejects, which results in increased environmental impact.

3.4 A Non-Toxic Environment

The use of chemical plant protection products is mainly an issue in primary production, that is in the cultivation phase of fruit and vegetables. In general, more chemical plant protection products per hectare and kg harvested product are used in the cultivation of fruit and vegetables than in other type of agricultural production. The use of plant protection products is also generally more intensive in fruit and berry cultivation than in the cultivation of vegetables. Figure 3.1 provides an overall picture of the use of chemical plant protection products in fruit and vegetable production in the EU.

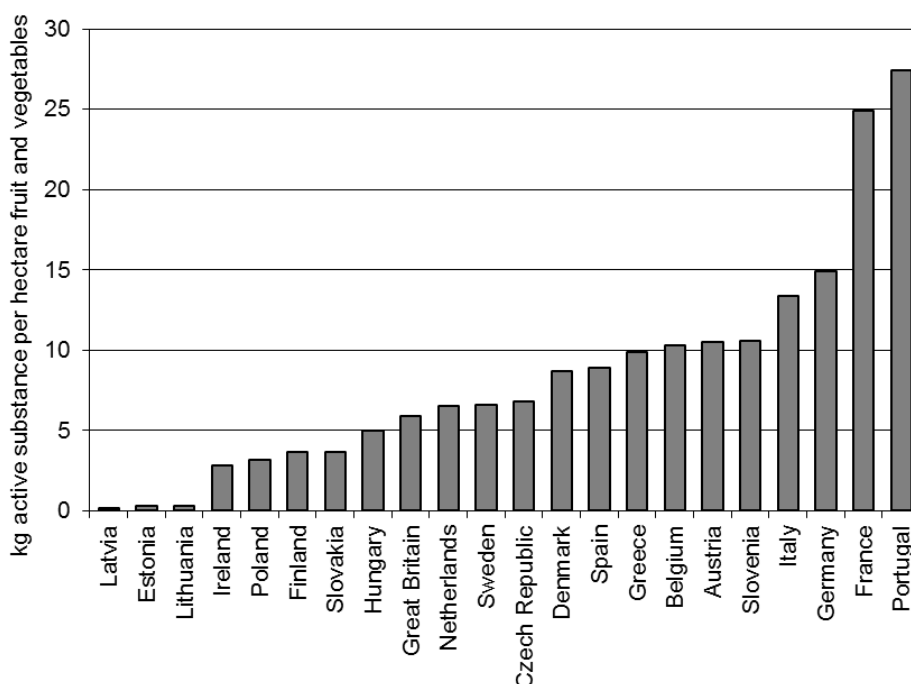


Figure 3.1. Plant protection product use in fruit and vegetable production in various European countries in 2003, expressed as average quantity of active substance per ha. Total use divided by the cultivated area (Europeiska kommissionen, 2007).

Swedish use of chemical plant protection products is low from an international perspective, which is not surprising given the relatively colder climate and more widely dispersed cultivation area, resulting in lower disease pressure and less need for disease control. Note that the statistics in Figure 3.1 are based on total use of plant protection products in fruit and vegetables, which is then divided by the respective acreage. This means that the statistics do not describe the dose per hectare actually used, but are highly dependent on the proportion of area treated with plant protection products.

The use of plant protection products in grapes is very high (Europeiska kommissionen, 2007). Grape cultivation in the EU requires more plant protection products than the entire cereal acreage. For example, the average use of plant protection products in French, Italian and Portuguese grape cultivation amounted

to 32, 18 and 50 kg of active substance per ha, respectively, in 2003 (Europeiska kommissionen, 2007), which may have contributed to the high overall use in Portugal (Figure 3.1).

Swedish carrot cultivation uses on average 2 kg active substance of chemical plant protection products per ha (Jordbruksverket & SCB, 2007a). The dose for parsnips as reported by Cederberg et al. (2005) was 3.5 kg per ha which, despite the different base years, (2006 and 2003) suggests a slightly higher use per kg product. For onions the national average in 2006 was close to 6 kg per ha (Jordbruksverket & SCB, 2007a).

In a recent study Hansson (2007) found that the quantity of active substance used for tomato cultivation in Sweden is 2 g per ton tomatoes ready for delivery (0.9 kg per ha), while in the Netherlands and Spain it is 15 and 289 g per ton tomatoes respectively (7.7 and 27 kg per ha, respectively). This implies that tomato cultivation in the Netherlands and Spain uses 7.6-fold and 145-fold more plant protection products respectively, than Swedish tomato cultivation. In this comparison chemical soil disinfection agents, which are often used in Spain, are not included. The great difference in the use of chemical plant protection products is partly caused by the Spanish cultivation mainly taking place in simple greenhouses with little opportunity for climate control, which results in major problems with diseases and pests, and by the yield being low in Spain. Cultivation in heated greenhouses makes it possible to control the climate so that the need for plant protection products decreases. In Swedish and Dutch cultivation biological plant protection works well, while Spanish crops require large amounts of chemical plant protection. In Spain there are also heated greenhouses of the northern European model, which result in lower use of plant protection products. The tomatoes from these more advanced greenhouses are usually exported to northern Europe, but a large part of those from simpler production systems are also exported there. (Hansson, 2007)

Lower yield results in significantly greater use of plant protection products for speciality tomatoes, calculated per kg tomatoes. In scenarios by Williams et al. (2006), the use of plant protection products for British classic vine tomatoes and loose cherry tomatoes was six-fold and four-fold greater, respectively, than in cultivation of classic loose tomatoes (calculated as g active substance per kg tomatoes). For vine cherry tomatoes the use was 24-fold greater than for classic loose tomatoes. The differences between the types of tomatoes are expected to be significantly less for tomatoes produced in Sweden, due to the smaller differences in yield levels (see Section 3.3.2).

Lagerberg Fogelberg and Carlsson-Kanyama (2006) indicate no quantities of chemical plant protection products in their case studies of carrots, onions and tomato, but they record the use of products that are red-flagged according to a model that takes into account acute toxicity, persistence, ability to cause cancer and disrupt reproduction, and whether the chemical is prohibited for use in Swedish farming according to the Swedish Chemicals Agency's pesticides register. The red-flagging indicates that greater potential environmental impact can be expected from these chemicals. The study by Lagerberg Fogelberg and Carlsson-Kanyama (2006) showed two red-flagged chemicals in Dutch carrot

cultivation and none in Swedish. Regarding onions, the same chemical was red-flagged in Sweden and Denmark. Three chemicals were red-flagged in Dutch tomato cultivation and none in Swedish. The Danish tomato nursery used no chemical plant protection products.

The average use of plant protection products in Swedish apple cultivation in 2005/2006 was 6.7 kg active substance per hectare (Jordbruksverket & SCB, 2007a). In apple orchards pest control is tailored to site requirements using forecasts and insect traps. Stadig (1997) clearly illustrated the problems of performing assessments based only on the quantity of plant protection products. He found that despite Swedish pesticide use being greater than in the New Zealand case and only slightly lower than in the French case, measured in active substance per kg apples, the Swedish cultivation clearly contributed the least toxicity from plant protection products in the three toxicity categories examined. Use of plant protection products in Swedish cultivation was therefore less toxic than that in the foreign apple orchards. In the countries from which Sweden imports apples, post-harvest use of chemical plant protection is common, while this is not permitted in Sweden (Wivstad, 2005).

Strawberries are very susceptible to grey mould, which attacks both foliage and fruits and is controlled chemically. In Sweden strawberries were treated with on average 5.3 kg active substance per ha in 2005/2006 (Jordbruksverket & SCB, 2007a). In the British strawberry scenarios (Defra, 2005) 400 litres per ha of chemical plant protection products were used for soil disinfection, which is not permitted in Sweden. Defra (2005) argues that Spanish strawberry cultivation probably uses more plant protection products than British due to the high pressure of diseases and pests. Most cultivation in Spain is located in polytunnels or microtunnels. The soil is disinfected chemically under black plastic before cultivation and the crop is annual with no crop rotation, so strawberry cultivation in Spain is conducted in monoculture. The cultivation takes place on sandy soils, which results in increased risk of leaching. Field edges are kept free of vegetation and are used as access roads. (Defra, 2005)

The intensive cultivation system used for industrial oranges in Spain (Sanjuán, 2007) probably includes heavy use of plant protection products, calculated per hectare. Sanjuán (2005b) indicated that the widespread and intensive cultivation of oranges in Spain has brought about environmental problems from the use of plant protection products. Ringblom (2004) reported that orange production in Florida takes place in intensive systems using large amounts of plant protection products. In Florida, on average 93 kg active ingredient per hectare were used in 2005 in orange cultivation, which comprised 220 000 ha at that time (USDA-NASS, 2006).

At the end of the 1990s, orange cultivation in Brazil represented 6.5 per cent of plant protection product use in the country, but orange was the crop that accounted for the largest use per hectare (Clay, 2004). Coltro et al. (2006) provide a weighted average for the cultivation of oranges for industrial purposes in the state of Sao Paulo of 1.3 g active pesticide substance per kg oranges (range 0.4-3.5 g per kg oranges). With an average yield of 33 tonnes per hectare (Coltro et al., 2006), this use of plant protection products is equivalent to 43 kg of active

substance per ha. Those authors also indicate that due to better water conditions and fewer problems with plant diseases and pests, orange cultivation is increasing in the southern part of Sao Paulo and that cultivation has intensified. If the average value cited by Coltro et al. (2006) is representative of the entire orange acreage in the Sao Paulo region, the use of plant protection products there roughly corresponds to at least 14-fold the use in the entire Swedish agricultural and horticultural sector.

When oranges are washed cleaning agents and solvents are used, often together with disinfectants such as chlorine, ozone or so-called SOPP (sodium orthophenylphenate) (Wardowski et al., 2006). Solvents are also used in washing. Oranges may also be washed with warm water and with high pressure washing.

Oranges which are stored or transported are waxed after washing to reduce the risk of disease and water loss. They are treated with fungicides, sometimes when waxed. Tiabendazole, imazalil (Smilanick et al., 1997) and SOPP are the main fungicides used post-harvest on oranges (FAO, 1997; Johnson et al., 2001; Thurman et al., 2005; Mossler & Aerts, 2006; New Guyana Marketing Corporation, 2007). The use of these fungicides is widespread, but data are lacking on the amount used per kg oranges and exactly which fungicides are today approved for post-harvest use and in which countries. Johnson et al. (2001) state that SOPP, tiabendazole and imazalil are approved for use in the USA. The Swedish National Food Agency's monitoring of pesticide residues (Anderson et al., 2007) has confirmed the presence of imazalil and tiabendazole in oranges in the Swedish market.

Clay (2004) points out the large amount of waste generated in orange juice production and notes that there are mountains of orange waste at many factories.

Martins et al. (2007) showed that by choosing less toxic compounds, the potential toxicity of pesticide use could be reduced significantly in Spanish orange cultivation.

Flysjö & Ohlsson (2006) calculated the use of plant protection products for melons from Costa Rica to be 15.5 g active substance per kg melons, including the chemical plant protection products added to the fruit during packing.

Some of the large quantities of plant protection products used in banana cultivation leach to the surrounding environment. Castillo et al. (2006) found that 40 per cent of drainage water samples from banana plantations in Costa Rica contained residues of plant protection products used on the plantations. Large quantities of nematicides (against nematodes) are used and these are very toxic. They were detectable for up to one month after application in the banana cultivations.

Lustig (2004) refers to a sample farm in Costa Rica which used at least 48 kg active substance per ha banana cultivation, of which 14 kg was nematicides (acutely toxic and classified in the highest toxicity class according to the WHO). This is probably a low estimate, given that other banana plantations were sprayed up to 60 times compared with the sample farm's 39 aerial sprayings. This does not

include the use of the insecticide chlorpyrifos, which is used in the bags that cover the banana stem during cultivation. Furthermore, the figure does not include the fungicides imazalil and tiabendazole, which are used on packed bananas in order to keep them blemish-free during transportation to Europe. According to Lustig (2004), the consumer requirement for unblemished bananas results in rejection of 25-30 per cent of bananas in the field and during packaging. This means that one-quarter of the acreage is sprayed solely for bananas that are rejected primarily for cosmetic reasons. Imazalil, tiabendazole, chlorpyrifos and propiconazole have been detected in runoff water from a banana packing plant in Costa Rica (Castillo et al., 2006). In addition to these plant protection products, kerosene is poured into the wounds left after surplus shoots are cut from the banana plant (Jordbruksverket, 2006a).

When working with chemical plant protection products, protective clothing and equipment for workers is important, something which is often overlooked in hot tropical countries. Dalvie et al. (1999, cit. Madeley, 2002) showed that workers on fruit orchards in South Africa had 10-15 per cent lower lung capacity than the reference group.

Treatment with anti-sprouting agents after harvesting has been permitted in Sweden since 2005 for onions that are to be stored for long periods. As regards potatoes, chemical anti-sprouting agents are used in many European countries, but are not permitted for ware potatoes in Sweden.

Juraske et al. (2007) calculated that people who eat Spanish tomatoes sprayed with Captan receive between 0.001 and 1 per cent of the dose applied, which demonstrates the risks of diffusion into ecosystems when using chemical plant protection products. In Sweden, plant protection products which contain Captan have been granted exemption in recent years, but only before fruit formation.

Pesticide residues are present in many of the products we eat. The Swedish Food Agency examined 1582 samples of conventionally produced fresh and frozen fruit and vegetables during 2005 and found residues in all product groups sampled (Andersson et al., 2007). Nearly all samples of citrus and bananas and papayas contained pesticide residues, while 90 per cent of nectarine samples and nearly as many of the samples of apples and pears contained residues. More than 50 per cent of the samples of plums, mushrooms, peppers, mangos, cucumber, melons, parsley, strawberries, lettuce (apart from iceberg), peaches, grapes and pineapples tested contained residues. Values above the maximum permissible concentration were found in mandarin, orange, lemon, papaya (60 per cent of papaya samples), pear, apple, pineapple (30 per cent of pineapple samples), peach, lettuce (apart from iceberg), strawberries, parsley, melon, cucumber, mango (20 per cent of mango samples), pepper (20 per cent of pepper samples), plum, leek, Chinese cabbage, spinach, figs, persimmon and avocado. Eight per cent of imports from non-EU countries contained residues that exceeded the statutory limit, while five per cent of samples from EU countries apart from Sweden contained levels above the limit. Of the Swedish samples the limit was only exceeded in one sample. The difference between domestic products and imported was marked, with domestic fruits and vegetables containing pesticide levels far below those reported for imported produce during the past ten years. (Andersson et al., 2007)

Organic cultivation does not permit the use of chemical plant protection products. Organic farming thus does not contribute to the spread of chemical plant protection products in the environment. Pesticide residues are found in Swedish surface water and groundwater (Adielsson et al., 2006), where chemicals from conventional agriculture comprise part of the contamination.

Due to contamination by water containing pesticide residues from conventional farming, organic fruit and vegetables may sometimes contain pesticide residues too. Bergkvist et al. (2007) reported that of 148 samples of organic fresh fruit and vegetables examined from autumn 2006 to autumn 2007, two samples were contained residues of chemical plant protection products. In one case the level was just above the detection limit and in the other sample the level was far below the permissible level. During the period 2003-2005, no traces of chemical plant protection products were found in any sample of organic fresh fruits and vegetables tested (Bergkvist et al., 2007). Wild fruit and berries picked outside areas with contaminated water do not risk being exposed to pesticide residues from conventional farming.

3.5 A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

Land use can be positive or negative depending on the form of land use and on the surrounding landscape and its existing characteristics regarding for example water courses, leaching risk, monoculture, landscape mosaic and corridors for plants and animals.

The environmental impact of land use is a function of the intensity of the agricultural system and its distribution in the landscape (area), which can be seen as the intensity at field level and the intensity at landscape level, respectively.

Monocultures reduce biodiversity. At the landscape level, devoting large areas of land to monotonous cultivation of a few crops has a negative impact on the environmental objective *A Varied Agricultural Landscape*. Growing smaller areas of the same crop close together forming a uniform landscape structure also has a negative impact on the varied agricultural landscape and, linked to this, probably also biodiversity. Since temporal monocultures, where the same crop is grown year after year, lack the decontaminating effect of a crop rotation, they also entail an increased need for plant protection products. Large-scale monocultures have been demonstrated for Spanish and Brazilian citrus fruit cultivation, banana cultivation and southern Spanish tomato cultivation. This type of homogeneous agriculture also occurs in Spanish strawberry cultivation, where vegetation is sparse, field edges are used to drive on and the surrounding fields are covered with various kinds of greenhouses (Warner, 2005; Defra, 2005). However, there is a lack of knowledge about the cultivation systems used for foreign cultivation of fruit and vegetables. Consequently, there are most likely widespread monocultures of various crops in different countries. Gilomee (2006) points for example to South Africa's large monocultures of fruit.

In large concentrated cultivation areas producing for a large external market, increased cultivation of the same plant type does not contribute to *A Varied Agricultural Landscape*, but on the contrary may be seen as negative in that monocultures at the landscape level increase.

For coarse vegetables, as for other field-grown vegetables, the above reasoning on intensity applies. The use of plant protection products, which is negative for the environmental objective *A Non-Toxic Environment*, is generally higher outside Sweden's borders, which suggests that the impact on biodiversity is higher for products of foreign origin.

The Danish Environmental Protection Agency (Miljøstyrelsen, 2006) points out that the storage of root vegetables in clamps covered with straw that is then broken down in the soil contributes to soil fertility. In addition to this, the authors highlight that the use of farmyard manure, upon which organic systems are dependent, also contributes to the soil's organic matter content and fertility.

In some regions of southern Spain and the Netherlands greenhouses are positioned close to each other. Where greenhouses are dispersed in the landscape and in areas which are not already dominated by similar crops, they do not result in an adverse effect on the environmental objective *A Varied Agricultural Landscape*. The impact of cultivation in greenhouses on *A Rich Diversity of Plant and Animal Life* depends on the intensity in the landscape and in cultivation, as well as the use of plant protection products.

Using wild fruits and berries does not have an adverse effect on the environmental objective *A Varied Agricultural Landscape* or *A Rich Diversity of Plant and Animal Life* provided that berry stocks are not overpicked. However, estimates of the amounts that can be harvested from existing berry stocks in a sustainable manner are lacking. For other types of fruit, more knowledge related to these environmental objectives is needed.

Citrus is cultivated in widespread monocultures using large quantities of mineral fertilisers and plant protection products, for example in Brazilian and Spanish orange cultivation. In an international perspective such production systems have an adverse effect on the environmental objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. Clay (2004) also indicates that blood oranges thrive in cooler climates and that they require cold periods in order for their red colour to be developed. The blood orange tree should therefore thrive on the steeper highlands in Africa, Asia and Latin America. In a limited part of these areas coffee is cultivated, but the majority is not agricultural land. Therefore a sharp increase in demand for blood oranges for juice production risks contributing to large-scale exploitation of virgin land or land susceptible to erosion. For oranges to develop their orange colour, which is required for a really high quality juice, the tree needs a slightly cooler tropical climate similar to that in southern Brazil or Belize (Clay, 2004). This may contribute to increased intensification of orange production in these areas and in regions with a similar climate, which would adversely affect the diversity of agricultural landscapes and of plant and animal life.

For tropical fruits, Flysjö & Ohlsson (2006) provide information about the very high use of plant protection products in melons, which adversely affects the environmental quality objectives.

Banana plantations in Costa Rica have an average size of approximately 250 ha (Castillo et al., 2006). Through their size they have a negative physical impact on the landscape and thereby an adverse effect on the environmental quality objective *A Varied Agricultural Landscape* in an international perspective. Their large turnover of plant protection products and soluble plant nutrients also adversely affects the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. This does not apply to organic bananas. In organic banana cultivation there are more plant species, more plant material is left in the field and soil erosion is lower, which generates less adverse impact on flora, fauna and the landscape. The supply of plant nutrients via farmyard manure means that organic banana cultivation depends on animals, which results in the landscape becoming more differentiated than in conventional banana cultivation. Pesticide leaching from conventionally cultivated bananas affects species composition also outside the banana plantations. Castillo et al. (2006) found clear changes in the species composition of invertebrate animals (insects) in water draining from banana plantations. Munoz-Carpena et al. (2002) showed leaching of nitrogen. In cases where rain forests or other species-rich vegetation are cleared to establish new banana plantations, this is very negative for the environmental objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*.

The biodiversity in the soil is favoured by the supply of organic material through farmyard manure, leys and green manuring, which are used to a greater extent in organic farming than in conventional. Since chemical plant protection products are not used in organic production systems, they have a very positive effect on the environmental quality objective *A Rich Diversity of Plant and Animal Life*.

3.6 Discussion and Conclusions

We need to increase our consumption of fruit and vegetables in order to meet the dietary guidelines. The distribution of fruit and vegetables within such an environmentally more advantageous diet is discussed in this section.

In recent decades, Swedish consumption of fruit and vegetables has shifted towards a larger proportion of salad vegetables, a larger proportion of imported fruit and vegetables and more tropical fruits.

Consumption of coarse vegetables and onions in general leads to less environmental pressure as regards the environmental objectives *Reduced Climate Impact*, *A Non-Toxic Environment* and *A Rich Diversity of Plant and Animal Life* than other vegetables, particularly in comparison with salad vegetables (both cultivated in the field and in heated greenhouses). They can be easily stored, with relatively small inputs and little waste, and are therefore also a good choice in the winter. Accordingly, it would be good for the environment if we were to consume

a larger proportion of coarse vegetables and onions. It would also be environmentally beneficial if a larger proportion of the fruit and vegetables people need to eat from a health point of view were produced domestically, with the emphasis on coarse vegetables, onions and apples (preferably home-grown).

Cultivation in heated greenhouses requires large quantities of energy for heating. The price to pay for cultivating tomatoes in the field in more southern countries is increased use of plant protection products, which is reinforced if the cultivations lie side-by-side, as in southern Spain. Through cultivation in shorter cultures, in non-heated greenhouses and through heating greenhouses with renewable fuels, the climate impact from greenhouse cultivation can be decreased. This suggests an increased proportion of Swedish tomatoes rather than Dutch or Danish. Due to the widespread and intensive cultivation in southern Spain, for example increased demand for tomatoes grown in greenhouses, polytunnels or in the field in that region would have an adverse effect on the environmental objectives *A Non-Toxic Environment*, *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. This in turn suggests an increased share of domestic salad vegetables.

However, we should not increase our total consumption of salad vegetables. In wintertime, it would be climatically advantageous to decrease the quantity of imported salad vegetables transported in trucks with controlled climate, which have a short shelf-life and risk creating large amounts of waste. In the winter imports of Chinese cabbage, onions and root vegetables are a climatically better choice than imported salad vegetables, due to their better storability and thereby reduced risk of waste in connection with transport and in the home.

Transport comprises a significant proportion of climate impact, which is to be expected from relatively unprocessed products such as fresh fruit and vegetables, particularly in cases where they are transported refrigerated. In order to decrease the climate impact from transport with climate-controlled trucks, transport time and distance are important. This advocates an increased proportion of imports of fresh fruit and vegetables from northern Europe rather than southern Europe. In comparison with frozen products, the consumption of products which are stored in the refrigerator in the home appears to be a better climate choice, provided that the refrigerated transport is not too long-distance or the amount of waste increases. Transport of locally/regionally produced fruit and vegetables (particularly coarse vegetables which are intrinsically more tolerant to handling than for example leafy vegetables) does not need refrigeration to the same extent as when transport time is longer, which suggests that an increased proportion of local and regional goods would be preferable. If transport could be shifted from road to railway, this would contribute positively to the environmental objective *Reduced Climate Impact*. In this case consumption of Swedish-grown fruit and vegetables would be affected most positively, because transport through Europe is avoided and the Swedish electricity mix, which powers Swedish trains, is significantly better than the European electricity mixes from a climate point of view.

For processed products, the climate advantage of the Swedish electricity mix means that it is advantageous to consume fruit and vegetables cultivated and processed within Sweden, as has been shown for frozen broccoli bouquets. For juices of the same raw materials, the Swedish electricity mix also gives a climate

advantage, but the overall picture can vary due to the origin of the raw material and logistics. Nevertheless, an increased proportion of juices from raw materials such as apples and root vegetables would make a positive contribution to the environmental quality objectives in comparison with for example citrus, grape and banana.

The significance of the electricity mix in combination with shorter transportation distance in refrigerated transport means that the processing of root vegetables and coarse vegetables (such as for root vegetable mixes) using the Swedish electricity mix is good for the environmental objective *Reduced Climate Impact*. Stuffed cabbage rolls containing meat from animals reared on Swedish grazing also contribute to the environmental objective *A Varied Agricultural Landscape*. The generally lower use of plant protection products in Swedish cultivation also contributes positively to the environmental quality objective *A Non-Toxic Environment*, which is reinforced if any of the raw materials are organically produced.

Swedish consumption of citrus, bananas and melons is high and has increased markedly. These fruits are imported and the cultivation of oranges and melons has been found to have greater climate impact per kg than apples. If transport to the Swedish border is added the climate impact becomes appreciably greater, irrespective of whether this involves boat transport from Central or South America or road transport from southern Europe. We should avoid air-freighted delicate fruits (for example mangos, papayas, cape gooseberries and fresh blueberries, raspberries and cherries during the winter) and vegetables (such as fresh beans, baby sweetcorn and asparagus from other continents) and regard these as luxury items for the occasional treat.

Less use of chemical plant protection products also suggests an increased proportion of domestic apples and decreased consumption of citrus, bananas and grapes. In general, the lower use of chemical plant protection products suggests that by consuming a greater proportion of Swedish fruits and vegetables we can contribute positively to the environmental quality objective *A Non-Toxic Environment*. For example this has been shown to have great significance regarding tomatoes. The environmental quality objective *A Non-Toxic Environment* also strongly advocates an increased proportion of organic fruit and vegetables.

A reduction in our banana consumption combined with an increased proportion of organically produced bananas and increased consumption of locally produced apples would be good for the environment. To start with, it would be good to replace conventional bananas with organic bananas in order to stimulate the development towards organic production. In the long term, it would also be good to reduce our total consumption of bananas in favour of domestic apples, since the organic production of bananas on the same scale as conventional bananas would not be agronomically possible. The yield difference between organic and conventional production would otherwise generate a situation where the banana acreage would need to be doubled, resulting in an intensification of the landscape (more banana plants in the landscape). A doubling based on the present agricultural system would bring about a negative impact on biodiversity, as well

as on the long-term ability to maintain organic production at increased disease pressure. Domestic apple cultivation amounts to almost 1200 hectares (Jordbruksverket, 2008). Accordingly, there is room for increased cultivation. An increased demand for organic apples, as for other organically produced fruits and vegetables, would also contribute to the fulfilment of the environmental objective *A Non-Toxic Environment* and to the reduced spread of toxins in the environment and to humans. Increased and more widely distributed domestic cultivation of apples of different varieties would also contribute to a more varied agricultural landscape. The coordination of transport services would then be equally relevant as for other products. Jones (2002) identified great opportunities to decrease transport-related energy use through more local apple consumption. By cultivating a number of different varieties which are harvested and ripened at different times, storage times could also be shortened somewhat.

Increased domestic cultivation of fruit and vegetables would be good for the landscape and crop rotations, so it would contribute to the environmental objectives *A Varied Agricultural Landscape* and *A Non-Toxic Environment*, as well as *A Rich Diversity of Plant and Animal Life*.

The studies reported above point to large variations between cultivations within the same region. Consequently, there is great potential for environmental improvement in cultivation and distribution as well as process technology and raw material supply. Fruit and vegetable producers are sparsely distributed in Sweden. This inhibits the spread of plant diseases and pests between cultivations, which provides an advantage as regards the environmental objective *A Non-Toxic Environment* but a disadvantage as regards transport, which adversely contributes to *Reduced Climate Impact*. This means that it is extremely important to optimise logistics and review possibilities to transfer transport to rail. In combination with local/regional production, this would contribute to a reduced climate impact.

Fruits and vegetables with a thin delicate skin (strawberries, blueberries, cape gooseberries) or large evaporation surfaces (lettuce) have a short shelf-life. For such products there is a high risk of large amount of waste in the home and earlier in the supply chain. This places great demands on packaging that allows air to circulate so that condensation does not build up and create favourable conditions for fungal diseases while at the same time not allowing too much water to evaporate so that the fruit/vegetable dries out. Packaging can contribute to a sharp increase in climate impact, but can also protect the product from damage and thereby contribute to less spoilage and losses. One way to reduce the environmental impact from products with a short shelf-life is to minimise the risk of losses. Accordingly, fresh goods at risk of large losses should be consumed after a minimal storage period. In order to minimise the time between harvest and consumption, it is better to source these delicate products from the local or regional area, which would require seasonal consumption of these fruits and vegetables.

More detailed studies of baby vegetables (e.g. babyleaf lettuce) are lacking. These baby vegetables are regarded as speciality products, similar to for example cherry tomatoes, and probably generally require more inputs per kg product. Therefore these would have greater adverse impact on the environmental objective *Reduced*

Climate Impact and *A Non-Toxic Environment*, expressed per kg product. From this perspective, it is therefore best to regard these baby products as luxury items for an occasional treat and which in comparison with their fullgrown counterparts comprise a small proportion of our fruit and vegetable consumption.

Using more home-grown fruit and cultivating more fruit and vegetables in domestic gardens would contribute to the environmental objectives *Reduced Climate Impact* (due to the decreased transport and use of fertilisers) and *A Non-Toxic Environment* (due to cultivation with very little or no chemicals). Just as the main purpose of berry picking in forests and in the countryside is recreation, fruit tree cultivation in private gardens does not primarily take place to secure or optimise the food supply, but rather gardening can be regarded as a health-promoting activity. Consequently, a proportion of the cultivation inputs can be allocated to activities other than the food supply. It is nevertheless important to minimise the use of fertilisers and other inputs which contribute to climate impact.

The significance of yield and type of fuel for the environmental impact of vegetables has been pointed out by several studies (for example Lagerberg & Brown, 1999; Van Woerden, 2001; Lagerberg Fogelberg, 2003; Williams et al., 2006). It is important that the yield does not become so low that energy use and climate impact become too large per kg product. Since the yield in organic production systems is almost always lower than in conventional, it is more important here to review measures which can increase the yield in organic production. In this regard it should be borne in mind that the management of farmyard manure, which gives rise to a climate impact, is also linked with the conventional system. Where there are farm animals there is manure, which is managed within the cultivation system, be it conventional or organic. However, many comparisons of conventional and organic systems assume that manure is only used in the organic system.

Because pesticide residues are found in such a large proportion of conventional fruit and vegetables, there is reason to further discuss whether this involves unnecessary exposure or whether it is essential. It is evident that residues are encountered to a significantly greater extent in imported fruit and vegetables, which suggests that an increased degree of self-sufficiency would contribute to both the environmental objective *A Non-Toxic Environment* and to the *Strategy for Non-Toxic, Resource-Efficient Cyclical Systems*. Greater land use is in itself not a problem in Sweden but there is a problem with agricultural land being abandoned, so it is an advantage if the cultivation system contributes to more open land. The greater land use for organic products thus involves no disadvantage. The precautionary principle applying to chemical plant protection products makes it desirable to increase the share of organic fruits and vegetables.

Replacing sweets with fruit and berries is good from a health viewpoint, but in terms of the environmental consequences of this change the data is still inadequate. The products replaced by increased consumption of fruit and vegetables is an interesting aspect of the net effect on the environmental impact. In this area there is a great need for knowledge about behaviour as well as efforts to provide information to consumers.

In conclusion, it would be environmentally favourable to eat more Swedish apples and more Swedish root vegetables (preferably cultivated on mineral soils) and fewer bananas, grapes and citrus fruits. It would be desirable to have a higher proportion of organic products, particularly bananas, citrus fruits and grapes. Increasing the proportion of processed products which are produced using ingredients from comparatively more local/regional areas and using Swedish electricity mix and avoiding products transported by air and road would also be positive. It would be desirable for our consumption of fruit and vegetables to be seasonally adjusted. Seasonally adjusted means eating more in accordance with the Swedish growing season and with Swedish products that can be stored well (with little spoilage and loss in relation to the environmental impact of storage) from harvest to consumption. It would include among other things a decrease in the consumption of tomato, cucumber, pepper and lettuce during the winter and instead eating these fresh vegetables during summer and autumn. During the winter and spring, it would mean eating more root vegetables (e.g. carrot, parsnip, celeriac, swede and beetroot), coarse vegetables (e.g. cabbage and onion), apples and sun-dried fruit, as well as other products which store well (e.g. Chinese cabbage). Products from the other Nordic countries, which follow the Swedish growing season, can also be included from a seasonal and environmental point of view, although not greenhouse products where the greenhouse is not heated with renewable fuels to the same degree as Swedish greenhouses or which include more pesticide use than in Sweden. It is not a matter of excluding for instance bananas, mangos or imported salad vegetables produced during the winter, but rather of regarding them as more of a luxury for occasional rather than habitual consumption. It is a matter of more frequently eating a greater amount of produce that has a lower environmental impact and less frequently choosing produce with a relatively high environmental impact.

4. Cereals, Rice and Potatoes

4.1 Recommendation and Consumption

The National Food Agency recommends that Swedish people eat bread with every meal, preferably wholegrain bread. This advice is equivalent to 6-8 slices of bread per day, or 185 g bread per person and day. Of this, 85 g should be wholemeal bread or crispbread. The advice includes on average 36 g of whole cereal or cereal flakes per day.

Cereal products are the principal source of carbohydrates and dietary fibre in the Swedish diet (Becker & Pearson, 2002). Cereal products, particularly wholemeal, contain a number of essential nutrients such as iron, potassium and magnesium, vitamin E, folate and other bioactive substances (Livsmedelsverket, 2007b). The latest national dietary survey of adults in Sweden showed that the intake of dietary fibre amounted to two-thirds of the desirable level (Becker & Pearson, 2002). This was the reason for the National Food Agency drawing up dietary guidelines on bread.

In SNÖ (Swedish *Nutrition Recommendations Objectified*), the National Food Agency recommends that Swedes eat potatoes five times a week, rice twice a week and pasta twice a week (Enghardt Barbieri & Lindvall, 2003). This is equivalent to daily consumption of 135 g potatoes, 20 g rice (equivalent to 60 g boiled rice) and 40 g unboiled pasta (equivalent to 120 g boiled pasta) (Enghardt Barbieri & Lindvall, 2003). In principle, the National Food Agency considers potatoes, rice and pasta to be nutritionally interchangeable (Enghardt Barbieri & Lindvall, 2003).

The latest dietary survey, *Riksmaten 1997/1998*, showed that bread consumption amounted to 100 g per day, of which 40 g was wholemeal bread (Becker & Pearson, 2002). The consumption of breakfast cereals amounted to 7 g per day, boiled potatoes 142 g, boiled rice 28 g and boiled pasta 40 g per day.

Table 4.1 shows direct consumption of cereals, rice and potatoes in Sweden. The consumption of bread and cereal products (including rice, cakes and pastries) in 2005 amounted to 105 kg per person (Jordbruksverket, 2007a). During the same year a total of 57 kg unprocessed potato and processed potato products per person were consumed. Between 1990 and 2005, consumption of unprocessed potatoes decreased sharply, while consumption of processed potatoes increased. The consumption of rice, pasta, soft bread, pastries and cakes also increased during the period.

Table 4.1. Direct consumption of cereals, rice and potatoes in Sweden during 1990 and 2005, expressed as kg per person and year (Jordbruksverket & SCB, 2007b)

	1990	2005	Change 1990-2005
Potatoes	60	46	-23 %
Processed potato products	7	11	+60 %
Rice	3.9	5.5	+40 %
Cereal products			
Flour (all kinds of cereals)	15.3	10.5	-30 %
Whole grain (oats and other cereals)	2.8	2.7	-5 %
Flour products (incl. ready mixes, gruel)	1.9	1.2	-40 %
Pasta products	4.3	8.7	+100 %
Crispbread	5.6	3.8	-30 %
Rusks	1	-	-
Soft bread	30.9	47.6	+50 %
Crackers, wafers and dry biscuits	6.2	5.1	-20 %
Buns	3.8	4.1	+7 %
Pastries, cakes and sponge cakes	4.6	11.5	+150 %

Imports of unprocessed cereals decreased by 30 per cent between 2001 and 2006 while imports of more processed products, such as flour, pastries, bread and pasta, increased by between 24 and 42 per cent (Jordbruksverket, 2007d). The countries of dispatch for cereal products are primarily Germany, Denmark and Belgium. The imported pasta is mainly from Italy.

Imports of early potatoes are decreasing. In 2004 Sweden imported 73 000 tonnes, which decreased to 52 000 tonnes in 2006 (Jordbruksverket, 2007d). However, imports of processed potato products increased considerably, from 55 000 tonnes in 2001 to 86 000 in 2006 (Jordbruksverket & SCB, 2007b). The countries of dispatch for processed potato products are primarily the Netherlands, Germany, Denmark and Belgium (Jordbruksverket, 2007d). Imports of rice increased from 55 000 tonnes to 76 000 tonnes between 2004 and 2006 (Jordbruksverket, 2007d). Rice is imported from Pakistan, Thailand, Italy, USA and India.

4.2 General Comments

4.2.1 Cereals

Wheat is the cereal that is globally grown on the largest acreage and comprises the greatest overall production (Fogelfors, 2001; Lantin, 2007). Since 1950 the world's wheat production has increased threefold (Lantin, 2007), but the wheat acreage has remained nearly the same since the 1960s (Clay, 2004). Spring wheat and winter wheat are primarily used for bread, crackers, breakfast cereals, alcoholic beverages and animal feeds. Barley is used for the most part for animal feeds but also for beer, malt liquors, bread and whole grain. Oats are first and foremost used for animal feeds but also for whole grain, bread and beverages. Rye is used mainly for bread.

4.2.2 Rice

More than half the people in the world have rice as their staple diet, making it one of the most important crops. Rice is cultivated in 113 countries, on a total of 1.55 million square kilometres, which is equivalent to 11 per cent of the world's arable land (Donald, 2004). Eighty per cent of rice cultivation takes place on water-covered fields which are either irrigated or rainfed. Almost 10 per cent of rice cultivation takes place on upland soils, in other words under dry conditions (FAO, 2003; Majumdar, 2003). Rice does not need to be grown in water-logged fields, but it is easier to obtain large yields in wet systems. Rice cultivation under dry conditions gives approximately one-third of the yield of paddy rice (Li et al., 2006).

In the past thirty years the use of inputs in rice cropping has increased dramatically (Mosier et al., 2000). The Green Revolution brought the introduction of the first high-yielding rice varieties, which are dependent on large quantities of inputs (Clay, 2004). The intensification of rice farming has resulted in environmental impacts, with declining yield levels as a result. The reasons for the drop in yield include increased problems with pests and diseases in rice fields and depletion of soil reserves of micronutrients (Clay, 2004). Waterlogged rice farming causes a large release of the greenhouse gas methane. Another problem is that the availability of water of good quality is decreasing globally. Approximately 75 per cent of rice production takes place in irrigated fields (Tabbal et al., 2002).

4.2.3 Potatoes

In Sweden, potatoes are grown in the whole country but the largest volumes are grown in the south. About 70 per cent of ware potatoes are produced in Skåne, Halland and Västra Götaland County (Jordbruksverket & SCB, 2007b). The earliest early potatoes are grown on Bjärehalvön and in Kullabygden in north-west Skåne, because these regions provide the best conditions for early planting. Potatoes for industrial use (for starch production) are grown along the east coast, from Kalmar to the southern coast of Skåne (Jordbruksverket & SCB, 2007b).

4.3 Reduced Climate Impact

4.3.1. Cereals

In cereal production emissions of greenhouse gases primarily derive from the production of mineral fertilisers and from nitrous oxide emissions from the soil. Energy use in cultivation is dominated by the production of mineral fertilisers.

Energy use and greenhouse gas emissions for the cultivation of cereals are shown in Table 4.2. In addition to the studies presented in the table, some other studies provide model estimates (for example Biermann et al., 1999; Gerhard & Laura, 2006; Williams et al., 2006; LCA Food Database, 2007). However, when comparing individual products it is important to use actual data from case studies.

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Tabell 4.2 liggande här
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The studies in Table 4.2 are not directly comparable due to different system boundaries and calculation methods, but they do show that the climate impact of cereal cultivation may be less in Sweden than in the USA. This is mainly because per hectare yield in the USA is significantly lower than in Sweden, which means that the use of mineral fertilisers and fuel in the USA is higher per kg cereal produced (Stadig et al., 2001; Anon, 2002).

Tidåker (2008) concluded that substantial improvements in the climate impact from conventional cereal cultivation can be expected when the mineral nitrogen fertilisers used are manufactured in processes with fully developed nitrous oxide reduction. The author exemplifies this with an update of wheat production in Mälardalen (Tidåker, 2003) (Table 2.3), in which climate impact dropped from 0.4 till 0.3 kg carbon dioxide equivalents per kg wheat.

Cederberg et al. (2005) found that the energy use was high for bread wheat fertilised with high mineral fertiliser doses. The high amount of nitrogen was explained by the fact that protein content is an important quality aspect in the production of wheat for the bread industry and is promoted by using higher amounts of nitrogen fertiliser.

Case studies concerning organic cereal cultivation are lacking, but a few studies provide model estimates. Cederberg et al. (2005) showed that greenhouse gas emissions from Swedish organic cereal farming were between 40 and 70 per cent of the emissions from conventional farming. In those studies the yield level in organic farming was assumed to be 65 per cent of that in conventional farming (Cederberg et al., 2005). According to a study modelling bread wheat cultivation in Great Britain, the release of greenhouse gases per kg product for conventional farming is about the same as in organic farming (Williams et al., 2006).

In general, less energy is used for organic cereal cultivation than conventional because of the use of energy-demanding mineral fertilisers in the latter (Cederberg et al., 2005; Grönroos et al., 2006; Williams et al., 2006). Studies modelling cereal cultivation show that total energy use is 35-50 per cent less in organic farming compared with conventional (Cederberg et al., 2005; Williams et al., 2006).

4.3.2 Rice

The climate impact associated with rice cultivation derives primarily from methane emissions from waterlogged rice fields (Breiling et al., 2005; Pathak & Wassmann, 2007). Ninety per cent of the overall methane release from the world's rice cultivation occurs in China and South East Asia (USEPA, 2006). Nitrous oxide is also generated in connection with rice cultivation (Pathak & Wassmann, 2007).

It is difficult to estimate the total amount of methane and nitrous oxide emissions from rice production. Methane emissions are affected by factors including soil type, number of harvests, the rice growing period, water levels in rice cultivation before and during cropping and the quantity of organic and inorganic material

(IPCC, 2006). The rice variety, type of fertiliser and fertiliser dose used also affect methane emissions (Guo & Zhou, 2007; Majumdar, 2003). Allowing rice fields to drain off at some time during the growing season can reduce the methane emissions from rice cultivation (Majumdar, 2003; Li et al., 2006) but at the same time results in mineralisation of nitrogen, which generates nitrous oxide (Li et al., 2006; Gou & Zhou, 2007). Other ways to reduce methane emissions include reduction of fertiliser dose and use of sulphate-rich fertilisers (Donald, 2004).

There are few studies on energy use and greenhouse gas emissions from rice cropping in relation to yield. In two studies from Japan and India, for example, emissions of greenhouse gases from rice cropping, including production of inputs, varied between 3 and 8 tonnes of carbon dioxide equivalents per ha (Breiling et al., 2005; Pathak & Wassmann, 2007).

Studies of the climate impact per kg rice ready for delivery are lacking. The climate impact presented in table 4.3 has been estimated using data on greenhouse gas emissions for rice cropping, including the production of inputs (Pathak & Wassmann, 2007), and FAO yield data (FAO, 2007) (Table 4.3).

Table 4.3. Energy use and potential climate impact of rice cultivation

	Energy use (MJ/kg)	Potential climate impact (kg CO₂-eq/kg)	Reference	Comments
Rice cultivation	-	0.9 ¹ -1.4 ¹	Pathak & Wassman (2007), FAO (2007)	Greenhouse gas emissions based on model estimates including soil, climate and cultivation system. Yield level of 2900 kg/ha from FAO data. Uncertain figures.

¹ does not include waste and losses

A Swedish study indicates that methane emissions alone from rice fields in the USA and Thailand amount to around 0.5 and 0.55 kg carbon dioxide equivalents per kg rice (Carlsson-Kanyama & González, 2007). These figures, which are based on FAO statistics and IPCC standard values, are considered relatively rough. After harvest, according to Lantin (1999), the total weight losses of rice ready for delivery amount to approximately 30 per cent.

4.3.3. Potatoes

Table 4.4 shows the climate impact and energy use of potato cultivation as reported in case studies and Table 4.5 summarises the results for 1 kg boiled peeled potato at the point of consumption.

The value given by Cederberg et al. (2005) for the climate impact of potato cultivation (at the farm gate) is of the same order of magnitude as that presented by Mattson et al. (2001; errata 6 Feb 2008). Both studies show relatively small

differences between conventional and organic cultivation. The release of carbon dioxide per kg potatoes was greater in the organic scenario, while the climate impact of conventional cultivation was dominated by nitrous oxide emissions (Cederberg et al., 2005).

Viewed over the entire cultivation-packaging-distribution chain, approximately half the climate impact derives from cultivation, one-third from transport and almost one-sixth from packaging (Mattson et al., 2001; errata 6 Feb 2008). When the supermarket, transport home and cooking are included in the life cycle, these later phases dominate completely for both conventionally and organically cultivated potatoes (Mattson et al., 2001; errata 6 Feb 2008). Furthermore, half the climate impact of conventional potato cultivation comprises nitrous oxide emissions, primarily from mineral fertiliser production, and almost half carbon dioxide from diesel use in cultivation and the production of inputs (Mattson et al., 2001; errata 6 Feb 2008). The proportion of climate impact attributed to transport is relatively greater for an unprocessed foodstuff such as potato.

Table 4.4. Energy use, expressed as secondary energy, and potential climate impact for cultivation of 1 kg potatoes, up to farm gate

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Harvest (tonnes/ha)	Reference	Comments
0.53	0.073	44.3	Cederberg et al. (2005)	Conventional farming of ware potatoes in Skåne. Model. Fuels and mineral fertilisers included.
0.81	0.083	25	Cederberg et al (2005)	Organic farming of ware potatoes in Skåne. Model. Fuels included.

Table 4.5. Potential climate impact and energy use, expressed as secondary energy, and potential climate impact for 1 kg boiled peeled potatoes in the home

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Harvest (tonnes/ha)	Reference	Comments
3 MJ (of which 0.6 MJ fuels and 0.05 MJ electricity in cultivation)	0.30 (of which 0.1 at the farm gate)	39.5-43.5	Mattson et al. (2001)	Conventional farming. Provinces of Halland and Östergötland. Cultivation-cooking in the household. Handling of waste, losses and rejects as well as handling of peelings included. Home transport and consumer stages account for 1.84 MJ.
3 MJ (of which 0.6 MJ fuels and 0.04 MJ electricity in cultivation)	0.34-0.35 (of which 0.1 at the farm gate)	25	Mattson et al. (2001; errata 6 February 2008)	Organic farming. Provinces of Halland and Östergötland. Cultivation-cooking in the household. Handling of waste, losses and rejects as well as

				handling of peelings included. Home transport and consumer stages account for 1.84 MJ. Yield is an assumed average yield for organic cultivation.
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The energy use in organic and conventional potato cultivation has been shown to be equally great (Mattsson et al., 2001; 2002; Williams et al., 2006) or higher for organic potatoes (Cederberg et al., 2005). In the study where energy use was higher per kg potatoes in organic cultivation, inputs of diesel and electricity per ha were approximately equally large in conventional and organic cultivation. However, the organic yield was significantly lower and rejects led to only 50 per cent of the harvest in the organic system being sold as ware potatoes (Cederberg et al., 2005).

Mattsson et al. (2001) and Cederberg et al. (2005) show the importance of lowering the number of rejects in reducing the environmental impact. Mattsson et al. (2001) also emphasise the importance of households returning potato waste to composting, since this waste gives a relatively large climate impact via methane release when placed in landfills.

4.3.4 Processed Products

Processed Cereal Products

In the case of bread, the climate impact is sometimes dominated by primary production (including transport to mill and milling) (Stadig et al., 2001; Anon, 2002) and sometimes by the baking phase (Braschkat et al., 2004; Grönroos et al., 2006). Few studies indicate exact figures for the climate impact. The parts of the product lifecycle shown to be significant for the environmental quality objective *Reduced Climate Impact* are therefore described below instead.

In a Swedish life cycle assessment of bread (including the production of raw materials, milling, bakery processes, packaging, storage and food store, including transport and waste management), the climate impact was lowest for bread baked at home, followed by bread in a smaller industrial bakery, because the ovens in both these cases were electric and therefore gained the climate advantages of the Swedish electricity mix (Andersson & Ohlsson, 1999). Following these were a local bakery with an oil-heated oven and last a large industrial bakery in which the oven was heated with natural gas. However, the authors of the study emphasise that the results only apply to the specific systems studied.

In a study of Swedish-produced hamburger baps (including wheat cultivation, production of other ingredients and packaging, milling, bakery processes and packaging, including transport) baked with equal parts of American and Swedish wheat flour, the climate impact was greatest from cultivation to production of wheat flour (including transport) (Stadig et al., 2001; Anon, 2002) (Table 4.6). The American wheat required twice as much energy as the Swedish due to the

transport over the Atlantic and the fact that wheat cultivation in the USA is more fuel-demanding than in Sweden. After baking, packaging contributed the next largest proportion of climate impact. According to the authors, great opportunities exist to reduce the climate impact of bread by using a greater proportion of wheat grown in Sweden and by reducing waste and losses in the bakery.

In a recent life cycle assessment of conventionally produced Swedish wheat flour, Cederberg and Flysjö (SIK, 2008) indicated a climate impact of slightly more than 0.5 kg carbon dioxide equivalents per kg flour. No further details are yet published about this study.

Table 4.6. Energy use, expressed as secondary energy, and potential climate impact for production of 1 kg hamburger baps

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Reference	Comments
15 (of which cultivation and transport to the mill 3 MJ)	0.93 (of which cultivation 0.47)	Stadig et al. (2001)	Wheat from USA and Sweden. Including cultivation, production of other ingredients, production of packaging, milling, baking, packaging, and transport.

In the study covering bread production on different scales cited above (Andersson & Ohlsson, 1999), the energy use was evenly distributed between cultivation and baking in the smaller industrial bakery and the local bakery. However, in the larger industrial bakery and in the home, energy use was dominated by the baking phase. Total energy use and emissions of greenhouse gases were greatest for the bread from the large industrial bakery, which also had the largest distribution area. The large energy use for the larger industrial bakery was explained by the longer distances involved in transport and by more energy-demanding packaging. The least energy was used for the bread produced in the local bakery, followed by the bread from the medium-sized industrial bakery. The home-baked bread required approximately 40 per cent more energy than bread from the local bakery.

In a study of bread produced in Germany (including cultivation, milling and bakery processes, including transport), three times more energy was used for home baking using a bread-maker than for bread baked in a large industrial bakery. Furthermore, a local bakery used twice as much energy per kg bread as the larger industrial bakery. Baking in the bakery or home was the stage of the bread's life cycle which demanded the most energy, on average 64 per cent of the energy use for the bread (Braschkat et al., 2004).

In a Finnish study of rye bread (including cultivation and milling of rye, production of other ingredients and packaging, bakery processes and transport to retailers) the bakery accounted for 72-83 per cent of the primary energy over the life cycle (Grönroos et al., 2006). Approximately one-fifth was used for cultivation of the rye and only 4-5 per cent for transport. Eighty-nine per cent of the electricity was used in the bakery. The energy use was 11 per cent lower per kg bread baked using organic rye compared with conventional rye. According to

the authors, this was explained by the energy use in the production of mineral fertilisers for conventional rye cultivation.

Processed Potato Products

Processing of potatoes can have a large potential climate impact. An estimate for an English factory which produces mainly chips and potato flakes indicates that the energy use for processing potatoes in this factory is on average 2.7 MJ (primary energy) per kg of potato processed (Foster et al., 2006). Energy use for the manufacture of chips was shown to be 5 MJ (primary energy) per kg chips and 36 MJ (primary energy) per kg potato flakes. According to the authors, the higher energy use of the flakes is explained by potatoes containing a lot of water, which is dried away in the manufacture of this product.

Climate Impact for Servings of Rice, Cereals and Potatoes

Table 4.7 summarises the climate impact for primary production (excluding transport) per serving, based on the figures given above. Before the consumption phase, waste, loss and rejects are not as great a problem for cereal products as for rice and potatoes. The emissions data given in Table 4.7 may show trends, but should not be used as specific measurements of servings, since they only cover primary production. Only primary production is included because it is difficult to provide general data on the processing of these foods as the variation is so great. There are few studies of processed products and even fewer disclose numbers for the processing phase or the significance of the consumption phase. Mattsson et al. (2001) showed that for a serving of peeled, boiled potatoes at the point of consumption, the part of the life cycle which comes after primary production can give rise to two-thirds of the total climate impact.

Table 4.7. Climate impact for rice, cereals and potatoes. Primary production only

	Serving size (g/serving ¹)	Losses and waste (%)	Potential climate impact (kg CO ₂ -eq/serving)	
			Min	Max
Rice	60	30 ²	0.07 ³	0.1 ³
Cereals	45	0 ⁴	0.014 ⁴	0.023 ⁴
Potatoes, peeled	170	50 ⁵	0.025 ⁶	

¹ KF & ICA (2000)

² Lantin (2007)

³ Greenhouse gas emissions based on Table 4.2, which contains uncertain values. Waste/loss is included, which means 85 g of harvested rice for one serving.

⁴ Greenhouse gas emissions based on Table 4.3. No waste/loss is included, which means 45 g of harvested cereals for one serving.

⁵ Mattsson et al. (2001)

⁶ Greenhouse gas emissions based on Table 4.4. Waste/loss is included, which means 340 g of harvested potatoes for one serving.

According to Table 4.7, rice has the greatest climate impact of the three foods listed. The difference between unprocessed Swedish cereal products and potatoes

appears to be small in terms of release of greenhouse gases from primary production, but more studies are required to establish this. From a climate point of view, a relevant difference between cereals and potatoes is that while cereals can be stored at room temperature, potatoes must be kept in cold storage.

Carlsson-Kanyama & Boström-Carlsson (2001) calculated the energy use for servings of various starch-based products from farm to table, including cultivation, storage, milling, factory processes, transport to the retailer and cooking in the home (Table 4.8). The results showed that cooking can account for a large part of the energy use of these foods. Boiled whole wheat and barley cereal required the least energy and fresh pasta and potatoes baked in the oven required the most energy, up to nearly six times more. The large differences are due to differences in energy use in cultivation, transport, factory processes, cooking method and cooking time. For relatively unprocessed products such as whole wheat and barley the cultivation stage dominates, while for fresh pasta made from imported durum wheat the processing stage and transport dominate the energy use. Transportation energy was greatest for fresh pasta, followed by rice, and transport contributed about one-third of the total energy use. The fact that transport involves long distances and fresh pasta requires refrigerated transport contributed to this situation.

Table 4.8. Energy use from farm to table. Packaging material, waste management, transport from retailer to household and dishwashing are not included. Based on cooking four servings of cereals, rice and potatoes (Carlsson-Kanyama & Boström-Carlsson, 2001)

	MJ/serving	g/serving
Swedish whole wheat, boiled	0.33	45
Swedish barley, boiled	0.37	40
Swedish potatoes, boiled	0.91	200
Rice, boiled	1.0	60
Couscous, boiled	1.0	60
Swedish-made pasta, boiled	1.2	70
Italian-made pasta, boiled	1.3	70
Italian-made fresh pasta, boiled	2.1	130
Swedish potatoes, baked in the oven	2.2	400

4.3.5 Transport

Table 4.9 provides some examples for transport of cereals, rice and potato products. It is important to observe that despite boat transport being regarded as energy-efficient, there is often additional road transport to the port, which can have great significance for the climate impact. In Table 4.10 the emissions of greenhouse gases are calculated for the transportation distances in Table 4.9, based on data from the Swedish Network for Transport and Environment (NTM, 2007). The calculations are based on the secondary energy use, so emissions during the production of fuel are not included.

Table 4.9. Examples of transportation distances (km) for some starch-rich foodstuffs

	Wheat, USA- Sweden	Wheat, Sweden	Pasta, Italy- Sweden	Potatoes, locally produced	Potatoes, regionally produced	Rice, Asia- Sweden
Lorry	500	50	600+600	50	50	300+750
Cargo ship, large	8 105					12 000
Cargo ship, medium	1 120					
Lorry	348		3 500			1 500
Distribution				20	550	100
	Stadig et al (2001)	Stadig et al. (2001)	Carlsson- Kanyama & Boström- Carlsson (2001)	Mattsson et al. (2001)	Mattsson et al. (2001)	Carlsson- Kanyama & Boström- Carlsson (2001)

Table 4.10. Climate impact from food transport¹

	Potential climate impact (kg CO ₂ -eq/kg)
Wheat, USA	0.25
Wheat, Sweden	0.003
Pasta, Italy	0.2
Rice, Asia	0.4
Potatoes, locally produced	0.005
Potatoes, regionally produced	0.04

¹ Vehicle fill rate was assumed to be 50 per cent for transport from farm to processing and for distribution. For longer transportation distances by lorry, a fill rate of 70 per cent was assumed.

4.4 A Non-Toxic Environment

4.4.1 Cereals

In Sweden, the increased intensification and development towards larger holdings in agriculture since the 1960s has given rise to more uniform crop rotations, which in turn has led to increased problems with certain pests and weeds (Jordbruksverket, 2002). For example, crop production in the plains districts of northern Götaland and Central Sweden is currently characterised by a large proportion of cereals, particularly winter wheat, and these areas (the plains districts of Uppsala, Örebro and Skåne County) contain the largest acreage treated with pesticides in Sweden (Jordbruksverket & SCB, 2007a). The average dose per unit area is also highest in these areas (Wivstad, 2005).

Sales of plant protection products decreased up to the early 1990s but have increased over the last decade (Cederberg et al., 2005; Jordbruksverket & SCB, 2007a). The number of hectare doses increased from 3.9 million in 1997 to 4.5 million in 2006 (SCB, 2007). The reason for the decreased use of plant protection products was the introduction of low-dose herbicides and lower doses in general.

However, the increased proportion of autumn-sown cereals in crop rotations has favoured weeds, consequently contributing to increased herbicide use (Jordbruksverket, 2002). Insecticides and fungicides are used to the same extent as before (Jordbruksverket & SCB, 2007a).

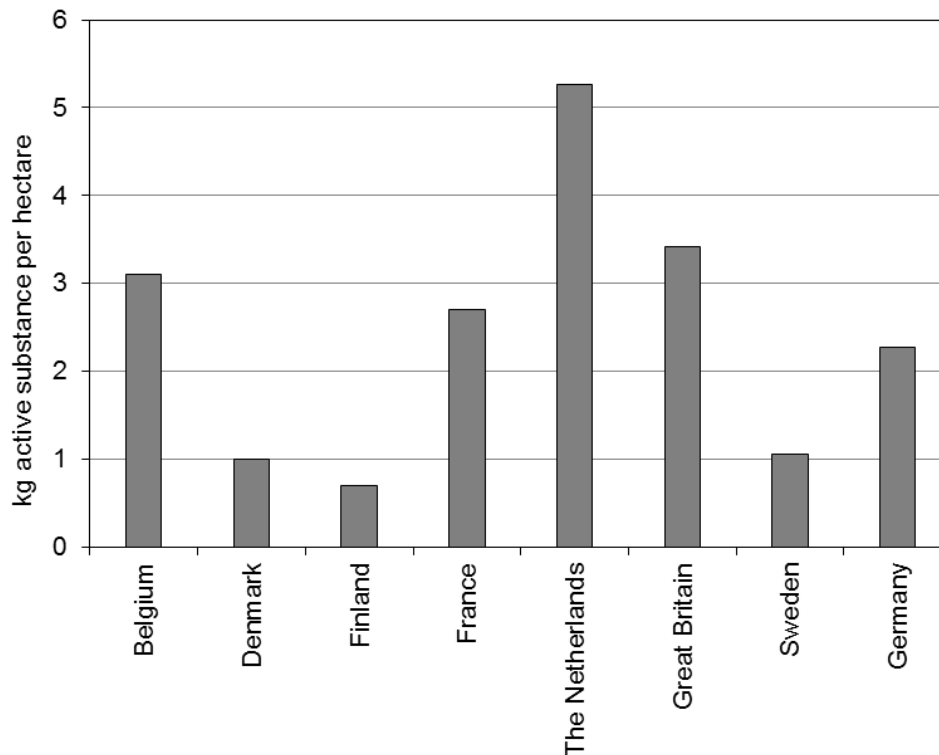


Figure 4.1. Plant protection product use in cereal cultivation in various European countries. Average use 2000-2003 (Europeiska kommissionen, 2007).

In a European perspective, Sweden is characterised by low pesticide use in cereal cultivation (Figure 4.1). In Belgium and Germany, the use of pesticides is two- to three-fold that in Sweden.

4.4.2 Rice

Some of the plant protection products used in Asia are classified as extremely dangerous or highly toxic by WHO (Heong & Escalada, 1998; Berg, 2001; Rice today, 2002; IRRI, 2004). Incorrect and heavy use of plant protection products in Asian rice cultivation can lead to health problems and harm to the environment (Rice today, 2002; IRRI, 2004; Khanh et al., 2006). In a survey in Vietnam in 2000, 97 per cent of 480 farmers responding used larger quantities of plant protection products than the recommended doses (Nguyen, 2002). Another survey in Vietnam showed that the majority (more than 80 per cent) of 120 farmers responding considered themselves to have health problems originating from plant protection products (Berg, 2001). One reason for the excessive use of plant protection products in many Asian countries is ignorance among farmers, for

instance pesticides are used at the wrong time or on the wrong pests (Heong & Escalada, 1998; IRRI, 2004).

The wide use of plant protection products has also brought problems with weeds, which have become resistant to herbicides in many rice-producing countries in Asia (FAO, 1998; Karim et al., 2004; Khanh et al., 2006).

4.4.3 Potatoes

Potatoes are susceptible to diseases, particularly potato late blight, which cannot be controlled satisfactorily without fungicides (Wivstad, 2005; Cederberg et al., 2005). This means that organic potato production involves reduced cropping reliability and significantly lower average yield. According to Swedish studies, yield can fall by 50 per cent and some years even more due to late blight (Wivstad et al., 2005). The use of resistant varieties has not solved the problem.

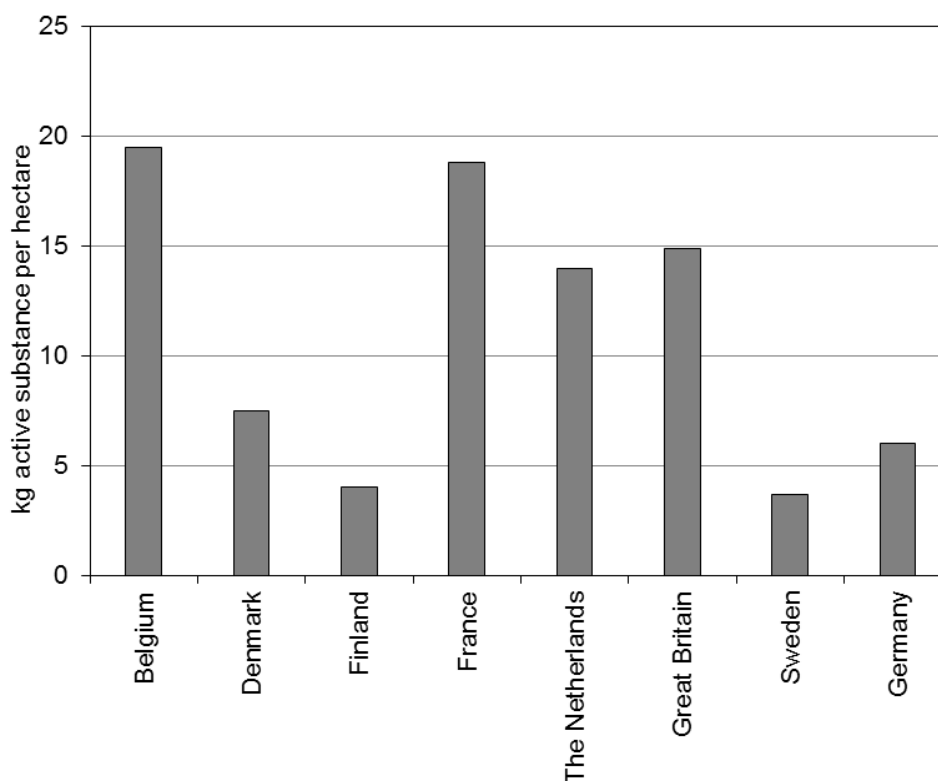


Figure 4.2. Plant protection product use in potato cultivation in various European countries. Average use 2000-2003. (Europeiska kommissionen, 2007).

Figure 4.2 gives an overall view of the use of chemical plant protection products (active substance per hectare) in potatoes in a selection of EU countries (Europeiska kommissionen, 2007). Compared with Sweden, use of plant protection products is three-fold higher in Belgium and five-fold higher in the Netherlands, which are among the countries from which Sweden primarily imports potatoes and potato products.

A number of substances used against potato late blight are classified as hazardous to health and harmful to the environment according to the Swedish Chemicals Agency (Wivstad et al., 2005). One aspect of intensive disease control with a few active substances is the risk of building up resistance in the fungus (Wivstad et al., 2005). Repeated treatment with plant protection products in potato cultivation increases the health risks to those carrying out the treatment and the risk of pesticides spreading into the environment (Jordbruksverket, 2002).

To reduce the problem of late blight, potatoes should not recur more often than every fourth or fifth year in the crop rotation (Wivstad et al., 2005). Potatoes should not be cultivated too frequently within a specific geographical area to prevent the spread of infection. Other measures include selection of potato varieties that have stronger resistance against potato late blight (Cederberg et al., 2005). Traditional varieties such as Bintje and King Edward have low resistance to potato late blight. The earliest potatoes in north-west Skåne are cultivated in the same fields year after year (without crop rotation), which increases the problem of soil-borne infection of potato late blight (Andersson, B, 2007).

In Sweden, use of chemical anti-sprouting agents during storage of ware potatoes is not permitted, but import of potatoes that have been treated with such agents is permitted (Andersson, G, 2007). Sweden has also banned the use of fungicides in the storage of ware potatoes and soil disinfectants, which are used in other countries. Soil disinfectants are most often used in very high doses per hectare and several of the most common active substances are associated with contamination of groundwater in the countries where they are used (Bergkvist, 2002).

4.5 A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

4.5.1 Cereals and Potatoes

Changes within agriculture have led to many of the plant and animal species that belong to the agricultural landscape currently being on the list of endangered species. Wild plant and animal life needs variation in time and space in order to find food, habitats and nesting grounds, migration routes and shelter. Consequently, a varied crop rotation is important (Holzschuh et al., 2007). Small farms have been closed down or merged together to form larger farms, obstacles such as field islets (mounds or small hills of moraine or rock frequently found in Swedish fields) have been removed and wetlands have been drained (Jordbruksverket, 2007e). There are fewer meadows, pastures and small-scale habitats today (Jordbruksverket, 2003a). Small-scale habitats have disappeared most in the plains districts where cereal cultivation predominates (Jordbruksverket, 2004a). One way to increase diversity would be to maintain and restore field edges and field islets in the fields and to keep the field plots small (Wivstad et al., 2005).

Sweden currently has less than 7-8 per cent farm land, which together with Finland is the least in the EU (Jordbruksverket, 2003b). The figure can be compared with Denmark, which has 63 per cent farmland. This means that it is important to keep farmland in production in Sweden in order to maintain variation in the landscape, which is essential for biodiversity.

For birds that breed in cereal fields, the vegetation can be too dense for some species, e.g. skylarks (Kvarnbäck et al., 2006). The authors explain this by the modern high-yielding agriculture forming dense stands, which are more common in conventional than organic cereal cultivation.

The specialisation of agriculture has resulted in a redistribution of plant nutrients from the areas with production of cash crops and little or no animal husbandry, primarily cereal farms in the plains districts, to areas with more animal-dominated farming such as the pastures and mixed farming areas of the south Swedish highlands. This redistribution is especially marked for phosphorus, which is bound tightly in the soil and therefore accumulates in the soil in areas where the quantities added exceed those removed (Eriksson et al., 1997; Andersson A et al., 1998).

The status and long-term productivity of arable land are affected by factors such as pH, nutrient availability, organic matter content, structure, texture, soil fauna and contaminants (Jordbruksverket, 2003a). There are no conclusive data on how different farming systems affect the properties of the soil. The separation of animal husbandry from cereal cultivation has led to a reduction in organic matter content in some soils. Nevertheless, the organic matter content of Swedish soils is generally good. Across the whole country, the proportion of soils containing less than 3 per cent organic matter is less than one in twenty (SCB et al., 2007). The organic matter content can be built up by cultivating perennial leys and by adding a lot of organic material (e.g. crop residues, organic fertilisers such as farmyard manure and compost). Organic matter content contributes to increasing the soil's ability to store and deliver plant nutrients, and improves soil structure and water retention capacity.

Biodiversity is not specifically favoured by potato cultivation but for genetic diversity it is important to have many potato varieties in cultivation. Waste potatoes can also be a food source for birds in the landscape (Wivstad et al., 2005). In potato cultivation the soil is tilled more intensively compared with other agricultural crops (Mattsson et al., 2002). This intensive tillage can lead to a reduction in the soil's organic matter content and to potato cultivation drawing down the organic matter content more than cereals, for example (Wivstad et al., 2005). Organic fertilisers are therefore important for crop rotations involving potato. The fact that potatoes are cultivated in ridges brings a greater risk of soil erosion and nutrient leaching (Wivstad et al., 2005). Potatoes are cultivated most often on lighter (sandy) soils, with an associated increased risk of leaching, particularly of nitrogen and potassium.

Technological developments in agriculture have led to machines becoming heavier, which increases the risk of compaction damage. Soil compaction is considered to constitute one of the greatest threats to the productivity of arable land (Naturvårdsverket, 2007).

Organic Cultivation

In general, the literature suggests that organic cultivation leads to greater biodiversity than conventional (Drake & Björklund, 2001; Belfrage & Björklund, 2005; Bengtsson et al., 2005). The most important factor for biodiversity is that the agricultural landscape is varied, in other words contains a variation of arable land, pasture land and forest edges where there are habitats and nesting grounds, migration routes, shelter and feed (Weibull & Östman, 2001; Bengtsson et al., 2005). According to previous studies this landscape mosaic, which to a great extent depends on local geographical, topographical and historical conditions, can have greater significance for biodiversity than the production system (Drake & Björklund, 2001).

In Sweden the transition to organic production has mainly taken place in less intensively farmed areas (Drake & Björklund, 2001). In these areas the differences in farming methods between organic and conventional farms are relatively small. For biodiversity in these areas it is thus important that the land is cultivated and kept open, irrespective of the farming system.

The cultivation system has greater significance in the field and its immediate vicinity. A study from Switzerland, based on long-term field research, established that there were more micro-organisms, springtails and earthworms in organically farmed soils than in conventionally cultivated soils (Mäder et al., 2002).

Four European inventories concluded that the species diversity in organic cultivation is greater for plants and also for animals such as birds, beetles, spiders, butterflies and worms (Drake & Björklund, 2001). One reason is considered to be the lack of chemical plant protection products which reduce the diversity and quantity of flowering plants. Factors such as the more varied crop rotations and larger proportions of ley in cereal-dominated areas also play a role.

Another study reported a statistical analysis of the results from 66 published scientific articles (Bengtsson et al., 2005). The articles reviewed were mainly from west European countries and a few from the USA and New Zealand. The results showed that organic cultivation systems have on average 30 per cent more species and that the individual density is 50 per cent higher compared with conventional cultivation systems.

Birds that breed in the field can be adversely affected by ploughing green manure fallows too early and by cutting leys (Kvarnäck et al., 2006). This can be a problem in organic cultivation, since in conventional cultivation it is not permitted to cut leys before the first of July, while organic leys are exempt from this rule.

Four European inventories in which organic and conventional cultivation were compared concluded that soil structure, biological activity and soil organic matter content benefit from organic cultivation and that the risk of soil erosion is decreased by organic cultivation (Drake & Björklund, 2001).

In organic cultivation the dominant nitrogen supply often comprises nitrogen fixing by legumes, where subsequent crops use the nitrogen supplied by these crops (Cederberg et al., 2005). Approximately 50 square metres of arable land are needed to produce one kg of nitrogen from nitrogen-fixing crops (Bergström & Geber, 2003). When fertilising with mineral fertilisers in conventional farming it is possible to adjust the nitrogen dose more directly according to the needs of the individual crop (Cederberg et al., 2005).

The acreage required in organic farming is significantly greater than in conventional farming due to lower yields in the organic system, which are caused by the low concentration of plant nutrients, especially nitrogen, resulting in less dense crops (Florén et al., 2006). In England, land use per kg conventionally cultivated wheat has been shown to amount to one-third of that for organic cultivation (Williams et al., 2006). In Germany the corresponding figure is 65 per cent of the area needed in organic cultivation (Braschkat et al., 2004).

4.5.2 Rice

In Asia, cultivation of rice has been carried out for thousands of years. Before the Green Revolution, the traditional paddy rice cultivations provided a habitat for a number of organisms such as fish, frogs, snails, insects and other aquatic organisms. Many of these occurred naturally, but some were introduced (for example various species of fish). For farmers and their families this diversity of organisms can represent the most important source of protein. The traditional rice cultivation systems that remain contain high genetic diversity through the hundreds of traditional varieties of rice that are in use (Donald, 2004).

Today, however, the traditional rice cultivation systems with large biodiversity are disappearing. Intensive rice cultivation with the use of mineral fertilisers and chemical plant protection products has led to the disappearance of many of the species that were found in traditional rice cultivation (Clay, 2004). The old traditional varieties of rice are also disappearing, since mainly new high-yielding varieties are cultivated in modern intensive rice cultivation systems. With the old varieties of rice, the natural resistance to pests which many of them had is also disappearing (Clay, 2004).

In the USA, the development of paddy fields has been one of the largest contributors to the reduced area of natural wetlands (Donald, 2004).

Terraced cultivation makes it possible to cultivate rice even along steep slopes in mountainous areas. When the paddy fields are divided into terraces they provide protection against soil erosion and landslides and can also act as protection against flooding following heavy rain (FAO, 2003; Breiling et al., 2005).

4.6 Discussion and Conclusions

From a climate perspective a serving of rice gives rise to a greater climate impact during primary production than a serving of cereals or potatoes. Rice is also transported a longer distance, which means that the environmental pressure of rice is even higher compared with Swedish cereals and potatoes. The difference between a serving of unprocessed cereal products and unprocessed potatoes appears to be small regarding emissions of greenhouse gases for primary production, but more studies are required to verify this. Based on the literature, one cannot conclude that there is a difference between unprocessed potatoes and processed cereal products such as pasta and bread. Certainly, it can be assumed that pasta and bread have a greater climate impact for production than unprocessed potatoes, but this can be partly offset by long-distance transport of potatoes. There is no basis for ranking processed cereal and potato products, but generally it can be said that where the processing requires the potatoes to be dried, for example in the production of crisps, this requires large amounts of energy since potatoes have a high water content. The energy use is also great for potato products that are processed and then frozen, since freezing and freezer storage in industry, supermarkets and households require large amounts of energy (Davis et al., 2006). The increased energy use entails a greater climate impact.

Swedish cereal production has been shown to result in lower emissions of greenhouse gases compared with American. There is no basis in the literature to distinguish Swedish cereal and potato production from European production in terms of greenhouse gas emissions and energy use. For imported products, however, transport to Sweden is added, which represents a significant percentage of the climate impact for these products. Local distribution and marketing may be advantageous in order to reduce the need for energy-demanding transport. Previous studies suggest that conventional and organic potatoes may have similar energy use and emissions of greenhouse gases, but due to the high unreliability in organic cultivation, waste may result in poorer performance of organic potatoes.

In the case of cereals, organic cultivation generally requires less energy and results in fewer greenhouse gas emissions compared with conventional cultivation. This is because the production of mineral fertilisers requires a lot of energy and generates nitrous oxide emissions. However great potential exists to reduce the climate impact from mineral fertiliser production (Jensen & Kongshaug, 2003; Tidåker, 2008).

When the Swedish environmental quality objective *A Non-Toxic Environment* is seen in an international perspective, the environmental load of conventional rice is considered to be greater than that of cereals and potatoes.

In international comparisons, the risks of pesticide use in Swedish agriculture can be regarded as small. Significant factors include an extensive approval process for new products and long-term work on training in handling and safety issues. In addition, smaller quantities of plant protection products are generally used in Sweden, Norway and Finland due to the relatively low pressure of diseases and

pests. This means that Swedish cereals and potatoes have less impact on the environmental quality objective *A Non-Toxic Environment* than imported products.

Expressed per unit area, the use of plant protection products is significantly higher in potato cultivation compared with cereal cultivation (SCB, 2007). In a case study of a cereal farm growing speciality crops, using the Swedish Chemicals Agency's farm-adjusted risk indicators gave a significantly higher environmental risk index for potatoes and other horticultural crops compared with cereals with regard to the use of chemical plant protection products (Cederberg et al., 2005). Methodology for relating these data to the content per food serving is lacking, however. Organically cultivated products are preferable based on the environmental quality objective *A Non-Toxic Environment*.

As regards potatoes, some varieties which have low resistance against potato late blight are still being cultivated. Newer varieties have greater resistance against late blight and can therefore contribute to reducing the use of fungicides. Potato can be cultivated throughout the whole country, which means that the conditions for local production are good, contributing to reduced transport.

There is no basis for ranking cereals, rice and potatoes as regards the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*.

Biodiversity is greater in organic cultivation than in conventional (see for example Bengtsson et al., 2005). Land use is greater in organic cultivation than in conventional, which is negative if food production competes for land with bioenergy production, but positive if there is surplus land and the landscape should be kept open. Sweden currently has a very small proportion of arable land. It is therefore important to keep arable land in Sweden to maintain variation in the landscape, which is a key factor for biodiversity.

Swedes today eat only 5-6 kg of rice (unprocessed) per person and year, which can be compared with 100 kg of bread and cereals and 46 kg of potatoes. Based on the environmental quality objectives *Reduced Climate Impact* and *A Non-Toxic Environment*, the low consumption of rice is an advantage, since the environmental load is greater for rice than for Swedish cereals and potatoes. However, there is currently a tendency for consumption of rice to increase at the expense of unprocessed potatoes. This entails an increased environmental load caused by the change in Swedish consumption.

Consumption and imports of processed potato products are increasing. The effects of increased processing of potatoes are uncertain, but processing and handling of frozen products in the food chain can be very energy-demanding. Depending on the type of energy used, this adversely contributes to varying degrees to the environmental quality objective *Reduced Climate Impact*. Moreover, the total transportation requirement probably increases when potatoes and other inputs are transported to the processing plant and to the consumer.

In the case of cereals too, consumption and imports of processed products are increasing. This implies that cooking in the home is decreasing. It is unclear how this affects the environmental impacts. For bread, it may mean reduced energy consumption, since it can be very energy-demanding to heat up a household oven to bake small amounts of bread. The amount of greenhouse gases released in the processing and cooking of food is dependent on the type of energy used. If the oven is heated using Swedish electricity the climate impact is relatively small. Increased imports of cereal products, as for potato products, probably adversely contributes to the environmental quality objective *Reduced Climate Impact*. The contribution of transport depends on the mode of transport and the transportation distance.

Some cereal-based products require wheat with a high protein content, which is obtained through high amounts of nitrogen fertilisation. It is mainly bread with a dense texture (for example hamburger baps and other white bread) which requires high protein content (Rydberg, 2001). The manufacture of pasta also requires strong gluten and high protein content (Mat21, 2002).

Large industrial bakeries generally place high requirements on flour quality and protein content (Rydberg, 2001). Since Swedish wheat does not always reach the high protein content required by large bakeries, this leads to the import of wheat from countries such as America, which require more energy in cultivation than Swedish wheat cultivation (Anon, 2002). This means that products and processing units (e.g. bakeries) which are able to use cereals with a lower protein content could generate less climate impact.

In conclusion, it would be environmentally advantageous to increase the share of locally produced potatoes and avoid dried potato products. An increased share of cereal products from more local areas (Sweden and its neighbouring countries) would also be favourable. It would be desirable to not increase rice consumption further, but rather to replace it with unprocessed cereal products or potatoes. Organic products have an environmental advantage in that they do not contribute to the dispersal of plant protection products in ecosystems and are likely to contribute to increased biodiversity.

5. Legumes

5.1 Recommendations and Consumption

Legumes for human consumption consist of various lentils, beans and peas, which are either used fresh, as sugar peas, or canned, frozen or dried. In the SNÖ report (Swedish Nutrition Recommendations Objectified), The National Food Agency proposes that the consumption of legumes be increased to 12 g of dried peas and beans per day, which is equivalent to one portion a week (Enghardt Barbieri & Lindvall, 2003). This means a threefold to fourfold increase in the average intake of approximately 3 g of dried legumes per day which Swedes reported in the national dietary survey *Riksmaten 1997-98* (Becker & Pearson, 2002). Frozen peas, sugar peas, haricots verts, wax beans, etc. are in fact regarded as vegetables, but are dealt with in this chapter about legumes. Nutritionally, legumes provide fibre, complex carbohydrates, vitamins such as thiamine and folate, and several minerals, particularly iron. The protein content is high and the fat content is in most cases low.

Sweden is a net importer of fresh and dried peas and beans (Jordbruksverket, 2007d). Frozen peas are an exception, with exports more than ten-fold greater than imports (Table 5.1). Between 2004 and 2006, imports increased while exports decreased.

Table 5.1. Sweden's imports and exports of peas and beans in 2006 (Jordbruksverket, 2007d)

	Imports	Exports
Fresh peas and beans (tonnes)	1 538	121
Frozen peas (tonnes)	2 024	23 755
Dried peas and beans (tonnes)	6 386	4 312

The domestic cultivation of brown beans takes place on Öland (Jordbruksverket, 2006b). The production is carried out by contract between grower and buyer. In 2006 the acreage was 646 ha, a decrease compared with previous years. The total annual yield between 1995 and 2006 was on average just above 1 100 tonnes of brown beans. The total consumption in Sweden amounts to approximately 3 000 tonnes per year, which means that imports cover the majority of the demand (Jordbruksverket, 2006b). Processing peas for freezing are grown on approximately 9 000 ha, primarily on contract in the region of Skåne and in western Sweden (Jordbruksverket, 2006b). The average total annual yield of processing peas in 1995-2006 was just above 40 000 tonnes.

Growing legumes in cereal-dominated crop rotations provides many benefits. Due to the nitrogen-fixing capacity of legumes, nitrogen fertilisers do not need to be supplied to these crops. This means that legumes are particularly interesting for

organic production. Other advantages are that subsequent tillage can be reduced and a more varied crop rotation means that the overall use of plant protection products can be reduced (Nemecek & Baumgartner, 2006). Legumes also have a good pre-crop effect, i.e. the yield of the following cereal crop is higher than if only cereals had been cultivated (Fogelfors, 2001). Depending on the legume cultivated, the increased amount of residual nitrogen in the soil can increase the risk of nitrogen leaching to varying degrees. Legumes can be infected by fungal diseases, e.g. pea root rot in the case of peas (Levenfors et al., 2001). To reduce the risk of such infections, legumes such as peas should not occur too often in the crop rotation.

Increased human consumption of legumes can take place by animal protein being replaced with vegetable protein. There is an abundance of vegetarian food products based on soya bean, while for example peas are seldom used as a protein raw material (Davis et al., 2006). One reason for this may be that development of vegetarian products has taken place in the USA and elsewhere, where soya bean farming is frequent. The majority of vegetarian protein products are still manufactured abroad. Moreover, soya bean has a high protein content and contains a good combination of amino acids.

Products based on soya bean include milk-free beverages and ice cream, as well as soya sausages and vegetarian mince. Dried soya beans are also available in Swedish grocery stores. The origin of these soya beans varies, with the USA, Canada, South Africa, France and Brazil being cited as country of origin (Risenta, 2007). GMO-free soya is often quoted as a specification requirement.

5.2 Reduced Climate Impact

A study from the 1990s analysed the energy use for pork and three different vegetables in a lifecycle perspective (Olsson, 1998). Swedish-produced pork meat was compared with domestic peas, brown beans and soya beans from the USA and Brazil. All alternatives were compared on the basis of the same quantity of dietary protein. The results showed that pork meat clearly had the highest energy consumption. Cooking in the home contributed significantly for legumes, but the difference between cooking the different alternatives was small in relation to the total consumption of energy. Cooking in commercial catering institutions gave only marginally lower energy consumption than cooking in the home.

In a detailed study carried out by Davis et al. (2006), a number of meal options were analysed. Meals were composed to have equivalent energy, protein and nutritional content. A pork chop could thus be compared with a sausage made of a certain proportion of pea protein, soya sausage and pea burger. All meals had an energy use of the same order of magnitude, around 14 MJ expressed as primary energy. The figure for pea burger deviated from this through its slightly higher energy use, which was because freezer storage was assumed in industry, supermarket and household. Freezing is necessary at present in order to handle the relatively small volumes involved. However, the contribution to the greenhouse effect differed to a greater extent. The meals with pea burger and soya sausage

had a lower climate impact (around 0.5 kg carbon dioxide equivalents) than the options that included animal protein (around 0.7 kg carbon dioxide equivalents).

A Dutch study which compared protein intake through pork and peas also concluded that the climate impact could be reduced very considerably by increased intake of vegetable protein (Aiking, 2006).

Because of their ability to fix nitrogen, there is no need for nitrogen fertilisation of legumes. The production of nitrogen fertilisers is associated with the release of the climate gases carbon dioxide and nitrous oxide and with energy use, of natural gas in particular (Jenssen & Kongshaug, 2003). However, in high-yielding soya bean cultivation in the USA, the soya bean crop is fertilised with nitrogen. Smil (2002) indicates that the average nitrogen dose amounts to 25 kg nitrogen per hectare. A life cycle assessment of snow peas from Guatemala for the Swedish market illustrated that the use of nitrogen in these cultivation systems was very high, despite sugar peas being a nitrogen-fixing crop (Flysjö & Ohlsson, 2006). Two different cultivation systems were studied based on data collected from 28 and 19 growers, respectively. The supply of nitrogen in the two systems amounted to 263 and 342 kg of nitrogen per hectare and year, respectively. Fertilisation together with high use of plant protection products and transportation from Guatemala to the consumer in Sweden generated a significant climate impact. The cropping phase alone in one of the systems studied generated more than 1.1 kg carbon dioxide equivalents per kg snow peas.

Deforestation and land use change in order to increase agricultural production accounts for over 90 per cent of the total carbon dioxide emissions in Brazil. Burning the crop residues releases additional carbon dioxide. When these effects are included, the climate impact from soya bean cropping is more than doubled and amounts to 1.6 kg carbon dioxide equivalents per kg soya beans (Jungbluth & Frischknecht, 2007). The conclusion is that it is essential to include the consequences of land use change when the climate impact from soya bean cropping is considered.

Transportation can also have a large effect on the energy use and climate impact of legumes. The contribution of transport to a product's climate impact depends to a large extent on the mode of transport used and the fill rate of the vehicle. Transport contributes a larger percentage of the product's climate impact for unprocessed products than for animal products (Nilsson & Sonesson, 2007). Air freight always makes a large contribution to a product's climate impact. Air freight of e.g. green beans from Latin America and Africa to the European market means that the environmental load from the transport itself far exceeds that of other parts of the life cycle (Soil Association, 2007).

In a study of the environmental impact of different legumes, yellow peas and brown beans grown in Sweden were compared with brown beans grown in the Netherlands and chick peas and pinto beans grown in the USA (Lagerberg-Fogelberg & Carlsson-Kanyama, 2006). The functional unit was based on protein content and varied between 0.9 and 1 kg cooked peas or beans. The study also compared the handling of dried products with preservation in cans. Canning meant that larger volumes had to be handled, which resulted in increased climate

gas emissions for transport. In addition, the packaging material contributed to increased emissions (Figure 5.1). In the case of dried peas and beans, cropping was the part of the chain which contributed most to climate impact. Irrigation of pinto beans contributed further to this climate impact. The consumption phase represented a smaller part of the total climate impact of legumes, although it was not negligible.

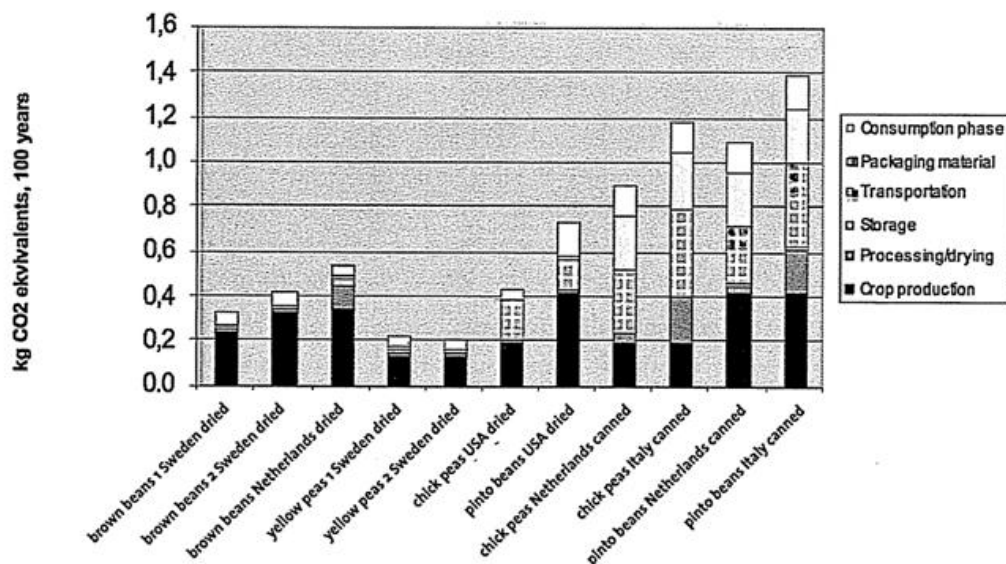


Figure 5.1. Potential climate impact of 11 types of legumes of different origins and different degrees of processing (Lagerberg Fogelberg & Carlsson-Kanyama, 2006).

The results from the study suggest that domestically produced legumes that are cooked at home have a lower impact on the climate than imported and processed legumes. For example, the climate impact of canned pinto beans was six-fold greater than that of domestic yellow peas. When the Dutch pinto beans were canned in Italy, the greenhouse gas emissions amounted to 1.4 kg carbon dioxide equivalents per functional unit, which can be compared with that of peas cultivated in Sweden, which contributed 0.2 kg carbon dioxide equivalents.

Many studies of the climate impact of legume crops performed since the late 1990s have used the IPCC's previous calculation method for nitrous oxide emissions, among other things. However, a literature study of nitrous oxide emissions for legume cropping concluded that these emission factors considerably overestimated the actual release of nitrous oxide (Rochette & Janzen, 2005) and the latest guidelines from IPCC (2006) no longer include biological nitrogen fixing in the legume crop as a supply of nitrogen to the farming system. Consequently, these modified emissions factors can result in the climate impact from legume cultivation generally being assessed as being lower in later life cycle assessments (from 2007 on).

5.3 A Non-Toxic Environment

Soya bean cropping in monocultures requires inputs of chemical plant protection products, which have an adverse impact on both the environment and the humans exposed to them (Fearnside, 2001). In the USA, plant protection products are used frequently in soya bean cropping. Herbicides are used on 98 per cent of the soya bean acreage and the most common herbicide used is glyphosate (USDA, 2007). Insecticides are used on 16 per cent of the acreage and fungicides on four per cent (USDA, 2007).

Between 1995 and 2007, the National Food Agency analysed 20 samples of dried peas, beans and lentils from around the world and did not detect any pesticide residues. However, imported beans with pods are a product group in which plant protection product residues have been detected. In nearly 20 per cent of all pod bean samples analysed in 2005, pesticide residues were above the permissible limit and more than 65 per cent of all samples contained detectable residues at levels below the permissible limit (Andersson et al, 2006). Particularly high contents were found in imported beans from Thailand. In total, the National Food Agency analysed 108 samples of fresh legumes from around the world from 2005 to 2007 and found residue levels below the permissible limit in 9 per cent of these samples and residue levels exceeding the permissible limit in 13 per cent. When the samples from Thailand were excluded, eight per cent of the samples exceeded the permissible limit. This is the same proportion of non-compliance as for fruit and vegetables (Andersson, 2007).

5.4 A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

The impact of legumes on the landscape and biodiversity is influenced by cropping location, distribution and variety. Soya bean cultivation has increased sharply in South America, especially in Brazil, Argentina, Bolivia and Paraguay. In fact, legume cultivation represents a most powerful threat to biodiversity in Brazil (Fearnside, 2001). The first expansion phase took place on the Brazilian savannah, the *cerrado*. This is considered to be the most species-rich savannah in the world, while at the same time it is the least protected ecosystem in Brazil. Endemic plant species associated with the *cerrado* are being seriously endangered by the heavy expansion of soya bean cropping. In recent times, soya bean cultivation has expanded in the Amazon region as a result of increased demand for soya and indirect government subsidies. An effect of the soya bean expansion is the major infrastructural efforts being made to allow input supplies and harvested products to be transported, which is opening up the way for further exploitation. Purchase and transport of agricultural lime constitutes the largest cost in soya bean establishment in the Amazon region (Fearnside, 2001). The need for lime is lower in recently cleared forest than in grasslands. Through continued expansion into the Amazon rainforest the need for lime can thus decrease, which thereby also reduces production costs.

The widespread expansion of the soya bean acreage in Paraguay, Argentina, Bolivia and Brazil is resulting in soya bean displacing other cultivation and in virgin land (including rainforest) being converted into agricultural land in the Amazon and elsewhere. In Paraguay, soya bean cultivation is expanding by approximately 250 000 hectares annually. Soya bean cultivation has resulted in the existing small-scale agriculture being converted into large-scale farming with little need for farmers. Since the acreages are large, irrespective of the owner of the land, plant protection products are often applied by airplane and there are examples of aerial spraying of villages and farms surrounded by soya bean fields. Herbicide-resistant soya (Roundup Ready soya) requires 10-20 litres glyphosate per hectare (Rulli, 2008). Such soya bean is grown in monoculture without crop rotation and with little or no tillage. Since soya bean leaves small amounts of plant residues after harvest, the soil is eroded by up to 30 tonnes per hectare and year (Brazil and Argentina). Soya beans lost at harvest generate a volunteer weed problem which is solved with e.g. the herbicide paraquat (Rulli et al., 2007).

In Argentina, more than 50% of all farmland is covered with soya bean, which has resulted in sharply decreased production of other crops such as cereals and vegetables (Rulli et al., 2007). Processing industries for these other crops have closed down, with increased unemployment as a consequence.

Legume cropping can also have a clear positive impact on the landscape and diversity. In the case of cropping of brown beans on Öland, environmental subsidies are available to farmers for cultivation, and thus conservation, of local varieties (Jordbruksverket & SCB, 2007b). This cultivation is an important part of the island's cultural heritage and contributes to a varied agricultural landscape and to preserving regional farming traditions.

5.5 Discussion and Conclusions

A transition from animal to vegetable sources of protein has consequences for several environmental quality objectives. According to studies previously referred to, a transition would lead to an obvious reduction in the climate impact. However, the type of meat replaced is an important factor to consider, since a further decrease in the number of grazing animals in Sweden would have an adverse impact on the agricultural landscape and on the biodiversity of natural grasslands. An interesting conclusion by Davis et al. (2006) was that a transition to more vegetable protein sources would not necessarily be beneficial from an energy perspective should the handling include freezing along the distribution chain. This appears to be partly scale-dependent, so if the volumes increase the prerequisites for refrigerated products will increase. The ways in which the product design affects storage and cooking are therefore important.

The replacement of imported legumes with domestic crops would provide several benefits. For example, domestic brown beans would be able to replace kidney beans imported from the USA to a certain extent. Increased variation in crop rotations that are otherwise dominated by cereals is important in order to counteract a number of fungal diseases of cereals. The use of plant protection products in Sweden is also more restricted than that in many other countries. An

increased proportion of domestic cultivation would probably mean less impact from transport, even if transport by boat is efficient from an energy and climate point of view. Processing of domestic legumes is lacking today, which means that soya bean still occupies a prominent position as a source of vegetable protein in various semi-prepared and prepared products.

On the Swedish market there is an abundance of various types of imported beans. However, there are no technical barriers to domestic cultivation of for example white, black and red beans in areas with warm, mild winters and light soils (Fogelberg, 2007a; b). Modern, hardy varieties of soya beans can be cultivated in southern Sweden. However, chickpeas are considered difficult to cultivate under Swedish conditions. Lack of practical experience in the cultivation of legumes that are currently imported constitutes an obstacle to increased Swedish cultivation (Fogelberg, 2007a; b).

The soya which is used in vegetarian products sold in Sweden is of varying origin. Given the adverse environmental consequences of soya bean cultivation in South America, the country of origin is an important aspect to consider. Using soya beans certified according to different sustainability criteria is a way to reduce the adverse environmental impact originating from the production of soya beans, according to Emanuelson et al. (2006). However, there is no appropriate certification system in place at present. If crop growing conditions are unknown, one option is to choose soya bean which has not been grown in South America. However, more knowledge is needed about the effects of large-scale soya bean cropping in for example Asia. Soya bean of Canadian and European origin is also available.

A seasonal diet can be an environmentally important aspect of fresh legumes. Long-distance transport, especially by air, of fresh legumes such as sugar peas and haricots verts produces a disproportionately large environmental impact. In general, drying and preserving means that peas and beans are available whatever the season. Dried products are preferable to frozen or canned if the transport distance is long.

A general conclusion about the environmental impact of various legumes is that they affect the environment less than meat, whether they are domestic or imported. On the other hand, imported legumes do not contribute to the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. However, the knowledge in many cases needs to be improved. For example, there is a need for more studies on the environmental impact of different products and different stages of the production chain.

6. Meat and Dairy Products

6.1 Recommendations

The SNO - Swedish Nutrition Recommendations Objectified – include around 100 g of meat raw materials and almost 40 g of cured meats and processed meat products per day, i.e. a total of approximately 140 g meat, cured meats and processed meat products. This quantity of meat provides iron for young women with a low energy intake. A higher intake contributes to an unnecessarily high protein intake, while the proportion of saturated fats is far too high (Enghardt Barbieri & Lindvall, 2003). The corresponding recommendation for dairy products is around 350 ml milk, soured milk and yoghurt (of which 200 ml with 0.5 per cent fat) and around 20 g of cheese (of which 15 g light cheese; less than 17 per cent fat) per person and day (Enghardt Barbieri & Lindvall, 2003). The consumption of dairy products is rather like the recommendations (Jordbruksverket, 2007c).

The intake of meat, poultry, cured meats and processed meat products according to the national dietary survey Riksmaten 1997/98 amounts to an average of 150 g raw material per day. This is somewhat overestimated, since dishes with meat are included (Becker & Pearson 2002). In general, meat consumption increased by 20 per cent between 1999 and 2005 (LRF, 2005). An adjustment of the intake to the 2005 level would result in an intake of 180 g meat per person and day. Swedish Meat has calculated that Swedes on average eat less than 110 g cooked meat, cured meat and processed meat products (excluding poultry), which is equivalent to 145 g raw material if it were all meat (Nilsson, 2007). The direct consumption of poultry in 2005 amounted to around 35 g per person and day (Jordbruksverket & SCB, 2007b). In total, daily consumption amounted to 180 g. The direct consumption of meat, poultry, cured meats and processed meat products is estimated at 181 g per person and day.

On a global scale, livestock production has a major impact on the environment and requires large areas. Of the world's total land area, 27 per cent is comprised of pasture land for grazing animals (Steinfeld et al., 2006). However, large parts of this land are unsuitable for food production other than grazing animals. Of the total land area, 11 per cent is comprised of arable land (Steinfeld et al., 2006). A large proportion of arable land is used for the production of feedstuffs, e.g. in the form of cereals, maize and soya bean. Around one-third of all cereals cultivated in the world go to animal feed (refers to 2002) (Steinfeld et al., 2006).

6.2 Production and Consumption of Animal Products

The number of dairy cows in Sweden has decreased steadily during the past decade. Milk weight delivered to dairies fluctuated between around 3 100 and 3 300 million kg per year during the last 10 years, with a tendency towards slightly

lower weights delivered during recent years (Jordbruksverket 2006c). Of the delivered weight of milk, around 42 per cent is consumed as fresh milk, fermented milk products (e.g. yoghurt, soured milk) and cream, while 37 per cent is used for cheese and 15 per cent for milk powder and condensed milk. Both imports and exports of milk, cream and cheese have increased. Imports of milk and cream amounted to just over 36 million kg in 2006 and originated primarily from Germany, Denmark and Finland. Production of organic milk has increased in recent years and in 2006 corresponded to more than five per cent of milk weight delivered (Jordbruksverket, 2006c). The total consumption of drinking milk and fermented milk products in 2005 was estimated at 1265 million kg (Jordbruksverket 2007c).

In Sweden, beef production is largely based on dairy breeds, since milk production has traditionally been important in the country. Meat from dairy cattle today accounts for almost 70 per cent of Swedish beef production. However, the number of dairy cows has decreased and the accompanying decrease in beef production has been partly compensated for by an increased number of specialist beef cattle. The Swedish consumption of beef has increased at a higher rate than domestic production, however, and is now slightly more than 230 million kg (refers to total consumption) (Jordbruksverket, 2007c). The difference is made up by increased imports. In 2006, 46 per cent of beef was imported, compared with 22 per cent in 1997 (refers to total consumption) (Jordbruksverket, 2006c). Since Sweden became a member of the EU, imported beef primarily comes from Ireland, Germany and Denmark. Imports from Brazil have also increased. Organic meat comprised 2.7 per cent of total wholesale beef in 2006. Of the organic beef, 60-70 per cent was sold as minced beef (Jordbruksverket, 2006c).

The production of pork meat rose in the beginning of the 1990s and then dropped sharply around 1999 as a result of poor profitability. In 2006, pork production was around 20 per cent lower than at the end of the 1990s. The consumption of pork meat has increased sharply since the beginning of the 1990s, but on average remained at approximately the same level during the last 10 years. The total consumption has increased from around 260 million kg in 1990 to around 320 million kg in recent years (Jordbruksverket 2007c). Imports of pork meat increased from 33 million kg to 86 million kg between 1997 and 2006. These imports of pork comes first and foremost from other EU countries, mainly Denmark, followed by Germany and Finland (Jordbruksverket, 2006c).

The consumption of poultry meat increased by slightly over 90 per cent after Sweden became a member of the EU. In 2006, Swedish consumption was calculated at approximately 150 million kg (refers to total consumption). The production was previously higher than the consumption, but has only increased by 38 per cent since Sweden's EU entry. Imports of poultry meat are increasing each year and in 2006 amounted to around 60 million kg. Around 75 per cent of the imports in that year came from Denmark, and 12 per cent from Germany. (Jordbruksverket, 2006c)

In recent years the number of sheep in Sweden has increased slightly. Today there are around 240 000 ewes and rams in the country and the level of production is around 4.2 million kg per year (Jordbruksverket & SCB, 2007b). Around 5 per

cent of the lambs that were slaughtered at Swedish Meats in 2006 were KRAV-certified. However, the consumption has increased more sharply than production and the degree of self-sufficiency is now barely 40 per cent. The total consumption in 2005 was calculated at just under 11 million kg (Jordbruksverket, 2007c). Imports of lamb meat and mutton come primarily from New Zealand, but also to a certain extent from Ireland, Germany and other EU countries. Imports are increasing mainly from EU countries (Jordbruksverket, 2006c).

The total consumption of reindeer meat is estimated at between 1.5 and 2 million kg per year during the 2000s and that of game animals at around 18 million kg. However, these figures are uncertain, since they are based on inadequate supporting data (Jordbruksverket, 2007c).

Between 1990 and 2005, direct consumption of fresh and frozen meat increased by 56 per cent to 43 kg per person and year (Jordbruksverket, 2007c). In addition, direct per capita consumption of frozen meat products and frozen ready meals containing meat increased sharply, from just over 5 kg in 1990 to nearly 18 kg in 2005. During the same period, direct consumption of cured meats, processed meat products and canned meats varied between 22 and 24 kg per person and year (this also includes smoke-cured loin of pork and ham) (Jordbruksverket & SCB, 2007b; Jordbruksverket, 2007c). However, the figures for e.g. game animals and offal are based on inadequate supporting data and are therefore uncertain (Jordbruksverket & SCB, 2007b).

Direct per capita consumption of fresh liquid milk and fermented milk products has decreased continuously since the 1980s and in 2005 was 138 kg per person and year, which can be compared with 176 kg in 1985. In 2005, direct consumption of cheese was slightly over 17 kg and of cream 9 kg per person and year, compared with just over 16 kg and 8.5 kg, respectively, in 1990 (Jordbruksverket, 2007c).

6.3 Reduced Climate Impact

Global livestock production, including cultivation of feed, transport and land use, accounts for about 18 per cent of total global greenhouse gas emissions. This corresponds to around 80 per cent of agriculture's total emissions of greenhouse gases, including emissions from land use and deforestation (Steinfeld et al., 2006). Methane, nitrous oxide and carbon dioxide each account for roughly one-third of the greenhouse gas emissions from global livestock production (Steinfeld et al., 2006). Between 1990 and 2020 methane emissions from animal digestion of feedstuffs is estimated to increase by nearly 40 per cent due to the number of animals increasing sharply, mainly in China, Africa and South East Asia (USEPA, 2006).

In the case of carbon dioxide, deforestation and land use accounts for a significant part of the emissions from livestock production. These emissions are largely caused by great quantities of carbon dioxide being released when forest in the tropics is converted to grazing land and arable land, e.g. where the vegetation is burned or the organic matter content in the soil decreases. The effects of

deforestation are most significant in South America (Steinfeld et al., 2006). Carbon dioxide released during deforestation is estimated to account for one-third of the climate impact of livestock production (Steinfeld et al., 2006).

Data on climate impact and energy use have been obtained from various life cycle assessments of livestock production. The assessments up to the farm gate typically include use of diesel, electricity, fertilisers, feed and other inputs. The environmental impact from home-produced and purchased feed includes cultivation, harvest, transport, storage and feed processing and inputs such as fertiliser, diesel, electricity, oil, etc. which are used in production. The assessments also include emissions of methane and nitrous oxide from soil, manure management, animal digestion, etc. Unless otherwise specified, energy use is expressed below as secondary energy, i.e. in the form it is used in the processes (e.g. diesel in tractors, natural gas for manufacture of mineral fertilisers and biofuels for heating).

6.3.1 Milk Production and Dairy Products

In terms of the entire life cycle of milk and dairy products (i.e. from the production of inputs used on the dairy farm to consumption of dairy products), production up to the farm gate generally accounts for the largest climate impact and energy use (Høgas Eide, 2002; Berlin, 2005; Foster et al., 2006). The focus in the following consequently lies on describing the climate impact and energy use up to the farm gate and how this impact can be reduced.

Milk Production on the Farm

The climate impact and energy use for milk production from dairy cows are summarised in Table 6.1. Data are expressed per kg energy-corrected milk (ECM), which corresponds to milk with around 4.0 per cent fat and 3.3 per cent protein.

Of the energy used up to the farm gate, a large proportion of electricity is consumed on the farm (around 80-90 per cent), while the use of fossil fuels in large part occurs outside the farm (Carlsson, 2004; Cederberg et al., 2007). The electricity is used e.g. for ventilation, lighting and operation of milking equipment. The high use of fossil energy outside the farm largely depends on cultivation and transport etc. of purchased feed. (Cederberg, 1998; Carlsson, 2004; Cederberg et al., 2007).

Energy use and greenhouse gas emissions during the production and distribution of feedstuffs vary between different feed materials (Cederberg, 1998; Cederberg & Flysjö, 2004a; Emanuelson et al., 2006). A large part of the feed for Swedish dairy cows consists of locally produced roughage (silage, hay, pasture, maize). The cow also receives various types of concentrates containing for example cereals, protein concentrate (e.g. from rapeseed and soya bean) and fibre (e.g. Betfor, which is a sugar industry by-product made from beet pulp and molasses). The soya bean in Swedish feed mainly comes from Brazil (Emanuelson et al.,

2006). Soya bean makes up around five per cent of the feed (in terms of dry weight) for dairy cows (Emanuelsson et al., 2006) but the energy use for transport from Brazil to Sweden is significant. The energy needed for the transport of soya bean by rail, lorry and cargo ship from South America to Sweden is estimated at 3-4.2 MJ/kg of feed. By comparison, the energy needed for the distribution of locally produced feed is estimated at around 0.03-0.3 MJ/kg (applies to e.g. transport of cereals from neighbours) and at a regional level 0.25-0.65 MJ/kg (e.g. transport of cereals between regions in Sweden) (Emanuelsson et al., 2006). In addition, Brazilian soya bean may be cultivated using large amounts of chemical plant protection products and may cause soil erosion.

In milk production, methane and nitrous oxide account for the greatest climate impact. Methane mainly arises from the animals' digestive system, but also from the storage of liquid manure, and nitrous oxide from the manufacture of mineral nitrogen fertilisers, storage of manure and the soil (Davis & Haglund, 1999; IPCC, 2006). Characteristics of milk production with generally small climate impact are efficient cows with good milk yield, efficient use of nitrogen in the cultivation of feedstuffs (i.e. low use of mineral nitrogen fertilisers and efficient utilisation of nitrogen in manure and nitrogen-fixing legumes) and a high proportion of locally and regionally produced feed (Cederberg et al., 2007). High-yielding cows are estimated to release more methane per cow and year than low-yielding cows, but when the methane release is allocated per litre of milk the emissions are lower. According to an equation presented by Cederberg & Flysjö (2004a) and Carlsson (2004), methane production from the cows' digestive system corresponds to just under 0.4 kg of carbon dioxide equivalents per kg of milk for cows which produce 6 000 kg of milk per year and almost 0.3 kg of carbon dioxide equivalents per kg milk for a production level of 10 000 kg milk. However, there are uncertainties and natural variations which affect the calculations of emissions of methane and nitrous oxide from biological processes. Methane emissions from animal digestion of feedstuffs depend on e.g. the feedstuff's energy content and digestibility and the emissions from stored manure depend on e.g. temperature, amount of manure, amount of available oxygen and storage unit design (IPCC, 2006).

Table 6.1. Energy use (expressed as secondary energy) and potential climate impact up to the farm gate for production of milk (per kg ECM)

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Reference	Comments
2.7 fossil energy (conv) 0.9 electricity (conv) 1.9 fossil energy (org) 1.0 electricity (org)	1 (conv) 0.93 (org)	Cederberg et al. (2007)	Comparison of 23 dairy farms in northern Sweden with conventional (conv) and organic (org) production. Information refers to 2005.
2.0 fossil (conv high) 0.6 electricity (conv high) 2.1 fossil (conv medium) 0.6 electricity (conv medium) 1.4 fossil (org) 0.7 electricity (org)	0.90 (conv high) (conv medium) 0.94 (org)	Cederberg & Flysjö (2004a); Carlsson (2004)	Comparison of 23 dairy farms in south-west Sweden with conventional (conv) and organic (org) production. The farms with conventional production were divided into two groups: high production for farms with >7 500 kg ECM per hectare (conv high), and medium-high production for farms with <7 500 kg ECM per hectare (conv medium). Data mostly refer to 2000-2002.
	1.3-1.5 (today) 1.0-1.1 (scenario)	Casey & Holden (2005a)	Irish milk production, i. e. current average (today ¹) and in a scenario with higher milk production (scenario ²).
	0.9-1.5	Casey & Holden (2005a)	Data from 10 Irish dairy farms, i.e. 6 conventional farms and 4 REPS ³ .
2.7 (intensive) 1.3 (extensive) 1.2 (org)	1.1-1.7 (intensive) 0.9-1.2 (extensive) 1.2-1.4 (org)	Haas et al. (2001)	Data from 18 dairy farms in Bayern, Germany, with intensive, extensive and organic (org) production. Data refer to average per kg of milk.
2.9-3.4 (conv, clay) 2.2 (org, clay) 3.3-3.6 (conv, sand) 2.5 (org, sand)		Refsgaard et al. (1998)	Based on data from 31 Danish farms. Comparison between various conventional (conv) and organic (org) production. The study also takes account of soil type, in this case clay soil (clay) and irrigated sandy soils (sand).
5.0 (conv) 3.1 (org)	1.4 (conv) 1.5 (org)	Thomassen et al. (2007)	Data from 10 conventional (conv) and 11 organic (org) dairy farms in the Netherlands.

¹ Current production corresponds to 4 800 litres of milk per cow and year. The higher figure for greenhouse gas emissions applies when all of the emissions are allocated to the milk. The lower figure applies when a proportion of the greenhouse gas emissions is allocated to the meat from culled cows and calves.

² More efficient production systems with higher yield per cow (6 000 litres), reduced use of diesel and mineral fertilisers, and only replacement animals as other cattle in the herds.

³ REPS = Rural Environment Protection Scheme. System for the reduction of environmental impact of agriculture. In this study, the intensity of milk production per cow and the greenhouse gas emissions per hectare were higher on the conventional farms. However, there is no significant difference in greenhouse gas emissions per kg of milk between the different systems.

Regional Differences

Two comparable life cycle assessment studies of milk production in north and south-west Sweden, respectively, indicate that total energy use is higher (around 40 per cent higher per kg of milk) for milk production in northern Sweden. The difference applies to both conventional and organic production (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). The difference is in large part explained by the fact that less cereal is cultivated in northern Sweden and that these farms therefore purchase more concentrate feed, which is more energy-demanding to transport. By cultivating a larger share of the feed for the cows in northern Sweden (Norrland) locally, the energy use would decrease (Cederberg et al., 2007). Other explanations for the higher energy use may be differences in mechanisation and housing period (Cederberg et al., 2007), where the longer housing period in northern Sweden means that more fodder has to be harvested and stored, and more electricity is needed for ventilation, lighting, etc.

In terms of climate impact, there was no distinct difference between milk production in northern and south-west Sweden according to Cederberg et al. (2007). The higher energy use for milk production in northern Sweden resulted in higher emissions of carbon dioxide, but this was offset by lower methane and nitrous oxide emissions. The cows in the Norrland study produced a relatively large amount of milk, which results in relatively low methane emissions from rumen digestion per kg of milk. The use of mineral nitrogen fertilisers was low in the Norrland production, which contributed to the nitrous oxide emissions from mineral fertiliser manufacture and soil being relatively low (Cederberg et al., 2007).

From a climate point of view, Swedish milk production seems to compare well internationally as regards both organically and conventionally produced milk (Table 6.1) (Cederberg et al., 2007). From a climate viewpoint, support in the literature is lacking for a higher proportion of imported milk reducing the climate impact of Swedish milk consumption. Moreover, imports result in longer transportation distances for the milk and thereby greater energy use and climate impact, which is not included when the results for production in different countries are compared directly.

Organic and Conventional Milk Production

According to the literature, the total climate impact does not appear to unequivocally differ between organic and conventional milk production (see e.g. Haas et al., 2001; Cederberg & Flysjö, 2004a; Cederberg et al., 2007). However, the proportions of different greenhouse gases in the total emissions may vary between the production systems. Nitrous oxide emissions appear to be greater in conventional systems, while methane is more important in organic production (Cederberg & Flysjö, 2004a; Cederberg et al., 2007; Thomassen et al., 2007). Compared with organic production, in general more nitrogen is brought onto conventional farms, for example in the form of mineral nitrogen fertiliser and purchased feedstuffs (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). The cows in organic systems generally produce less milk, which results in higher

methane emissions from rumen digestion, expressed per kg of milk (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). A common explanation, which has recently started to be questioned and is the subject of new investigations, is that organic cows eat more roughage, which takes a longer time to break down in the rumen than feed concentrate and consequently gives more time to produce more methane (Thomassen et al., 2007).

Comparisons between production systems are also affected by the method and unit used. In an Irish study in which two production systems with different production intensity were compared, it was shown that greenhouse gas emissions were higher per hectare in the more intensive production system, while no difference could be determined when the emissions were compared per kg of milk (Casey & Holden, 2005b).

Several studies indicate that the energy use per litre of milk is lower for organic than for conventional milk production (Table 6.1). This is mainly due to differences in feeding and fertilisation strategies, as the organic farms generally use smaller quantities of purchased feed and do not use mineral fertilisers (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). However, it is difficult to compare the results from different countries against each other, since conditions determined by nature, rules and regulations, practices in conventional agriculture etc. can differ. However, the literature suggests that in several countries there may be differences in energy use between the different types of farming.

The literature provides no clear-cut support for advocating either organically or conventionally produced milk to reduce the climate impact. It is possible to reduce the climate impact in both organic and conventional milk production, e.g. using efficient cows with good milk yield, efficient use of nitrogen and a high share of locally and regionally produced feedstuffs (Cederberg et al., 2007). However, there are other differences between organic and conventional production which generate greater effects for other types of environment impact, see following sections.

Dairy, Processing and Distribution

In terms of the entire milk chain, most climate impact and energy use is generated up to the farm gate (Høgaas Eide, 2002; Berlin, 2005; Foster et al., 2006). A life cycle assessment of Hushållsost, a semi-hard cheese (including among other things cultivation of feedstuffs, milk production, transport, dairy, distribution to shops, consumption in the household and waste management), concluded that greenhouse gas emissions up to the farm gate made up just over 90 per cent of the total climate impact (Berlin, 2002). In a life cycle assessment of semi-skimmed milk (1.5% fat) (including among other things cultivation of feedstuffs, milk production, transport, dairy, shops and households), the corresponding figure was also around 90 per cent (LRF, 2002).

After the farm gate, processing, distribution and waste management of packaging can contribute a large proportion of the climate impact and energy use. This applies especially to packaging with a lot of material per kg of food (e.g. milk in

glass bottles, even if the bottles are used several times) and dairy products with a low degree of processing (Sonesson & Thuresson, 2001; Sonesson & Berlin, 2003; Foster et al., 2006). In the life cycle assessment of semi-skimmed milk cited above, one-quarter of the total energy use after the farm gate was for packaging (LRF, 2002). A study of three different large Norwegian dairies showed that electricity use in the smallest dairy (7 million litres/year) was significantly higher than in the other dairies. One explanation was washing-up, which can be an energy-demanding process, and the need for system start-up even when only small volumes are processed (Høgaas Eide, 2002).

In general, transport to the dairy and distribution of milk and milk products to wholesale and retail contributes a small proportion of the milk chain's energy use and emissions of greenhouse gases (Høgaas Eide, 2002; Sonesson & Berlin, 2003). However, the transport from point of sale to the consumer's home can be more important, since it often takes place by car (Sonesson & Thuresson, 2001; Sonesson & Berlin, 2003; Berlin, 2005). A current trend is for dairies to become fewer, larger and increasingly more specialised, with some specialising in mainly producing fresh milk products and some others producing mainly cheese (Berlin, 2005). This can result in longer transport distances between farm and dairy, and between dairy and wholesale, as well as different transport patterns. By choosing products with a small proportion of packaging and reducing transport by private car between shop and home, the environmental impact from dairy to waste management can be reduced (Sonesson & Berlin, 2003).

6.3.2 Meat

Regarding the entire life cycle of meat production, i.e. from the production of input goods which are used on the farm to the consumption of meat, production up to the farm gate generally accounts for the greatest climate impact and energy use (LRF, 2002). The focus in this chapter is therefore on describing the climate impact and energy use up to the farm gate and how this impact can be reduced.

Beef

The climate impact and energy use of beef production is summarised in Table 6.2. The 'Comments' column summarises the geographical location and production systems of the study object and explains the abbreviations used in the columns. The data in Table 6.2 are taken from various life cycle assessments and refer to climate impact and energy use up to the farm gate. The units specified are per kg of boneless and fat-free beef. For conversion of data from the literature specified per kg of live weight, the proportion of boneless and fat-free meat was assumed to be equivalent to 40 per cent of live weight.

Beef production is partly done with specialist beef cattle breeds (e.g. Charolais, Hereford and Simmental), and partly with culled dairy cows and calves from dairy cows (e.g. Swedish Red Cattle and Swedish Holstein). Information relating to meat from dairy cows is marked 'dairy cows' in brackets and information relating to meat from beef cattle breeds is designated 'suckler cows'.

Table 6.2. Energy use (expressed as secondary energy) and potential climate impact for production of beef (1 kg boneless and fat-free beef)¹

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Reference	Comments
42 (dairy cows)	15 (dairy cows)	LRF (2002)	Swedish beef production from dairy cow breeds. Includes meat from culled cows and breeding of bull calves as by-products of milk production ² .
44 (conv, dairy cows) 27 (org, suckler cows) 24 (org, dairy cows)	19 (conv, dairy cows) 22 (org, suckler cows) 19 (org, dairy cows)	Cederberg & Darelus (2000)	Beef from i) young bulls from dairy cows, conventional production (conv, dairy cows), ii) young beef animals from suckler cows, organic production (org, suckler cows), and iii) simulation of system with steers from dairy cows, organic production (org, dairy cows). Data from a farm in Halland (western Sweden) ² .
10 (suckler cows)	24 (suckler cows)	Cederberg & Nilsson (2004a)	Organic beef production in ranch operation. Data from a farm in Skåne ^{2,3} .
	28 (suckler cows) 18-23 (dairy cows)	Casey & Holden (2006)	Irish production, i.e. with systems typical for Ireland with cattle breeds (suckler cows) and with breeding of calves from dairy breeds (dairy cows).

¹ In converting literature data expressed per kg live weight, the share of boneless and fat-free meat was assumed to be 40 per cent of live weight.

² In the case of beef production there are also by-products with economic value, primarily hides. In this table the literature data were recalculated so that energy use and emissions of greenhouse gases of these by-products are not considered, i.e. the meat carries the entire environmental impact of production. In the source literature 90 per cent of the environmental impact is allocated to meat and 10 per cent to by-products.

³ Ranch operation is a very unusual form of cattle rearing in Sweden. 80 per cent of the energy use is diesel. 70 per cent of the greenhouse gas emissions consist of methane from animal digestion.

Some studies suggest that climate impact of beef from dairy cow breeds is lower than that from beef breeds (Cederberg & Darelus, 2000; Casey & Holden, 2006). The most important reason is that the environmental impact from dairy cows can be divided between the milk and beef produced by the dairy cow, while the environmental impact from beef livestock is completely attributed to beef production. This means e.g. that methane emissions from the animals' digestive systems may be higher per kg meat from beef livestock than from dairy cows, since methane from the dairy cow is in large part attributed to the milk, while the methane from beef cattle breeds is entirely attributed to beef production (Cederberg & Darelus, 2000). In a dairy herd, some of the heifer calves are needed to replace culled dairy cows. The other calves are reared for meat production and are thus seen as by-products of milk production. This means that only a small part of the dairy cow's environmental impact is allocated to veal, while the environmental impact from suckler cows is entirely attributed to veal.

There are different allocation principles for how the environmental impact from dairy cows is divided between the beef and milk produced, e.g. with the starting point from the financial value or weight of the products. Calculations of the potential climate impact of beef are therefore also affected by the choice of allocation principle (Cederberg & Stadig, 2003; Casey & Holden, 2006). Studies do not suggest that there are any clear differences in total greenhouse gas emissions between intensive and extensive beef production from beef cattle. However the proportion of the total emissions for each greenhouse gas may vary (Cederberg & Nilsson, 2004a). In an extensive system in which the livestock are largely reared on pasture, the fattening period is longer. In intensive production, in which the animals are kept indoors for longer periods and receive concentrate and processed feed, more diesel and other inputs are used to cultivate and produce the feed, which contributes to a larger proportion of carbon dioxide and nitrous oxide (Cederberg & Nilsson, 2004a).

In a life cycle assessment of beef (Cederberg & Darelus, 2000), a system with conventional young bulls was compared with a system with organic young cattle from suckler cows and with a future system with organic steers from dairy cows. The calves from the dairy cows were regarded as a by-product from milk production, while the resource use and impact of keeping suckler cows, replacement animals and bulls for breeding were included in the alternative with suckler cows. The energy use was greater in the conventional system than in the organic systems, which was primarily due to greater energy use for conventional feed production and a long grazing season with energy-saving feed in the organic alternatives (Cederberg & Darelus, 2000). The study found no differences in climate impact between the conventionally and organically reared livestock of dairy breeds. However, the climate impact from the beef cattle breeds was slightly higher, since all greenhouse gas emissions from the suckler cows were allocated to beef production. A difference between bulls and steers is that steers have less ability to put on muscle and they easily become fat on high levels of feed. In order to achieve the same carcass weight, steers therefore need to be reared with lower intensity for longer and they also need more maintenance feed. This results in higher methane emissions from digestion per kg of meat from steers than from bulls (Cederberg & Darelus, 2000).

Reliable and comprehensive data on the climate impact of Brazilian beef are currently lacking, but there are many indications that it could be relatively high. Brazilian beef cattle rearing nearly always takes place on extensively managed pasture. Half the beef production occurs in the '*cerrado*' savannah region in Central Brazil. The use of supplementary feeds and mineral fertilisers is very small. Energy use for rearing should therefore be very low, but energy for transport and export of the beef has greater significance. The dry periods on the savannah and the warm, humid climate in the Amazon contribute to low fertility of the cows (around 0.6 calves per cow per year) and slow livestock growth, which contribute to high slaughter age (often 3-4 years) (Kumm & Larsson, 2007). According to IPCC guidelines, methane emissions from the digestive system of cattle are an estimated 56 kg of methane per animal and year (refers to Latin America) (IPCC, 2006). Roughly estimated, this is equivalent to 4 tonnes of carbon dioxide equivalents during the lifetime of a beef animal, or around 20 kg carbon dioxide equivalents per kg of boneless and fat-free meat. In addition, the

conversion of rainforest to pasture land contributes to a significant amount of carbon dioxide being released (Steinfeld et al., 2006; Kumm & Larsson, 2007), which was not taken into account. In addition, no account was taken of methane and nitrous oxide emissions from manure on the pastures, the climate impact of the mother animal or greenhouse gas emissions from transport of the beef from Brazil to the consumer. Even though these estimates are uncertain and rough, they indicate that moving towards an increased share of Brazilian beef cannot be justified as a way to reduce the climate impact of Swedish food consumption.

A recent life cycle assessment of Japanese calf production calculated the energy use at 170 MJ per kg of meat from mature animals, mainly for the production and transport of feed. The greenhouse gas emissions were calculated at 36 kg carbon dioxide equivalents per kg of meat (Ogino et al., 2007). Compared with the results presented in Table 6.2, these values seem to be high. The differences between the studies may be due to variations in e.g. forms of production, feeding strategies, animal growth rates and their age and weight at slaughter. In the Japanese study, e.g. energy for cultivation, production and transport of feedstuffs was relatively high, since a lot of feedstuffs, even roughage, are imported and the animals are not grazed outdoors (Ogino et al., 2007). In addition, the calving interval is relatively long (15 months), which contributes to the cow's emissions of greenhouse gases being allocated to each calf for longer.

From a climate point of view, the data in the literature suggest that Swedish beef production stands up relatively well in international comparisons.

Pig Meat

The data in the literature on the climate impact and energy use in pig production are compiled in Table 6.3. The 'Comments' column summarises the geographical location and production systems of the study object and explains the abbreviations used in the columns. The data in Table 6.3 are taken from different life cycle assessments and refer to climate impact and energy use up to the farm gate, expressed per kg of boneless and fat-free pig meat. The greenhouse gas emissions in the table do not include the effects of changes in organic matter content and how this affects the net storage or release of carbon from the soil (also see 6.7 Discussion and Conclusions). The risk of decreased organic matter content in cultivation of cereals, which is the main feed for pigs, is currently considered not to be a serious problem for Swedish arable land. High yields leading to high production of crop residues and straw, which are left in the field, contribute to maintaining the organic matter content (e.g. Mattsson & Larsson, 2005; Jordbruksverket, 2007f).

In pig production (up to the farm gate), a large share of greenhouse gas emissions originates from feedstuffs, i.e. from cultivation, transport, storage and processing, if any. Around 85 per cent of the feed consists of cereals. In cereal production, fertilisation (with manure and mineral fertilisers) and the manufacture of mineral nitrogen fertilisers contribute to much of the greenhouse gas emissions, primarily in the form of nitrous oxide (Davis & Haglund, 1999). In the production of feed concentrate (minerals and protein feed, e.g. soya, rapeseed meal, peas), fossil

carbon dioxide from cultivation, transport and processing contributes to much of the climate impact (Cederberg & Darelius, 2001). The choice of feed has great significance for reducing the environmental impact from pig production (Cederberg & Flysjö, 2004b; Strid Eriksson et al., 2004). The environmental impact can e.g. be reduced through use of domestic protein feeds such as rapeseed and peas instead of soya bean and by adjusting the composition of amino acids in the feed, possibly by adding synthetic amino acids, in order to improve feed utilisation by the pigs (Strid Eriksson et al., 2004).

Table 6.3. Energy use (expressed as secondary energy) and potential climate impact for production of pork (1 kg of boneless and fat-free pig meat)

Energy use (MJ/kg)	Potential climate impact (kg CO ₂ -eq/kg)	Reference	Comments
4.7 (electricity) 0.4 (renewable) 17 (fossil)	4.8	Cederberg & Darelius (2001)	Data from one integrated pig farm in Halland (western Sweden).
20 (fossil) 2 (electricity)	4.8-4.9	Cederberg & Nilsson (2004b)	Model. Two farms with organic pig production. Sweden.
16 (animal welfare) 15 (environment) 18 (quality/cost)	4.1 (animal welfare) 3.6 (environment) 4.4 (quality/cost)	Cederberg & Flysjö (2004b)	Model. Three future pig production systems in Sweden. The scenarios focus on animal welfare (animal welfare), environment (environment), and high productivity at low cost (quality/cost) respectively. Scenario "environment" represents conventional production systems in Sweden.
	6.5	Skodberg et al. (2003)	Model. Danish pig production. Includes slaughter house, but this accounts for only 2% of the greenhouse gas emissions ¹ .
35 (conv) 49 (org) 40 (red label)	5.1 (conv) 8.8 (org) 7.7 (red label)	Basset-Mens & van der Werf (2005)	Model. Three French production systems: conventional (conv), organic (org) and standardised quality label (red label). In the two latter alternatives the piglets are reared outdoors up to weaning ² .

¹ Data in Skodberg et al. (2003) are expressed per kg carcass weight. To convert the data, it was assumed that boneless and fat-free meat comprises 60% of the carcass weight.

² Data in Basset-Mens & van der Werf (2005) are expressed per kg live weight at slaughter. To convert the data, the dressing-out percentage was assumed to be 75% of live weight and boneless and fat-free meat was assumed to comprise 60% of the carcass weight.

Compared with cattle, the methane release accounts for a smaller share of greenhouse gas emissions, since pigs are monogastric and the methane emissions from their digestive system are thus significantly lower. According to the IPCC guidelines for the calculation of greenhouse gas emissions, methane production from the digestive system of pigs is about 1.5 kg methane per pig and year (IPCC, 2006). A significant proportion of methane emissions can derive instead from the

storage of liquid manure. The magnitude of these emissions depends on e.g. temperature (low temperatures result in lower emissions) and the storage unit design (some type of covering results in lower emissions) (IPCC, 2006).

Feed production also has great significance regarding energy use in pig production, and the production of feed concentrates can account for a relatively large proportion of the energy use. Use of domestic protein raw materials such as peas and rapeseed meal can give lower energy use than if the feed contains imported soya bean (Cederberg & Flysjö, 2004b). Through improved use of the nitrogen in the manure, the need for mineral fertilisers can be reduced, thereby also reducing energy consumption for fertiliser production (Cederberg & Dareljus, 2001). Of the energy which is used in animal husbandry, a large proportion comprises electricity for ventilation, feed preparation and heat lamps for the piglets (Cederberg & Dareljus, 2001).

Since the production of organic pork is limited in Sweden today, there are few general data about resource consumption and environmental impact from this form of production (Cederberg & Nilsson, 2004b). There are also relatively large differences between the rules and regulations for organic pig production certified by KRAV and the way conventional pig production is generally carried out. In organic production, animal welfare is emphasised and the pigs must e.g. have access to outdoor grazing (KRAV, 2007). Differences between organic and conventional pig production may result in the measurements and models developed to assess the environmental impacts from conventional production not being directly applicable to organic pig production (Cederberg & Nilsson, 2004b). Differences between the forms of production may also cause the feed consumption to be higher for organic production. This depends on e.g. the fact that the pigs move around more and that the protein in the feed is not always well adjusted to the pigs' needs, since synthetic amino acids are not allowed according to KRAV rules. Electricity use is expected to be lower in organic production, since the animals stay outside more (Cederberg & Nilsson, 2004b).

The total emissions of greenhouse gases do not seem to differ greatly between the reported studies. From a climate point of view there is consequently nothing that clearly points out that the proportion of pig meat of some particular origin or from some particular form of production should be changed in order to reduce the climate impact from Swedish pork consumption. However, favourable conditions for using feed efficiently and for using feed products with low emissions of greenhouse gases are two important parameters to reduce the climate impact of pig production.

Chicken and Other Poultry Meat

Production up to the farm gate accounts for the largest environmental impact from chicken meat, primarily from feed production (i.e. cultivation, transport, storage and any processing) (Johannisson & Olsson, 1997; Amundsen & Thorsen, 1999; LRF, 2002). Feed for chickens mainly consists of grain and protein feed. In a life cycle assessment which included rearing of chicks (data from a producer that can be assumed to be representative of Swedish chicken production), slaughter, the

wholesale and retail stages and cooking in the home, the total energy use was 28 MJ and greenhouse gas emissions were 1.8 kg carbon dioxide equivalents per kg of fresh, boneless meat (LRF, 2002). Production up to the farm gate represented 75 per cent of the climate impact and 70 per cent of the total energy use. A large proportion of the energy, in this case in the form of straw, was used for heating the chicken house. If fossil fuel is used instead to heat the house, the climate impact increases significantly. A more recent study reported the climate impact for Swedish conventional chicken to be 1.6 kg carbon dioxide equivalents per kg of fresh boneless meat (Tynelius, 2008). That study concluded that from a climate point of view, it is most important to replace protein feed with more locally or regionally grown alternatives such as rapeseed and peas. It also pointed out the importance of increasing plant nutrient utilisation of chicken manure, replacing fossil fuel with biofuel for heating and reducing waste in all steps.

In a study of the environmental impact from food production in England and Wales (Williams et al., 2006) the greenhouse gas emissions for conventional poultry production (chicken and turkey) were calculated to be 4.6 kg carbon dioxide equivalents per kg of carcass weight (i.e. including bones). In comparison with energy use and climate impact from other animal species poultry was reported to perform very well because of efficient feed use, high daily weight gain and very low proportion of breeding stock (one hen can produce around 250 chickens per year). For organic production the climate impact was reported to be 6.7 kg carbon dioxide equivalents per kg of carcass weight. The difference is due to the organic chickens in this case being kept for a longer time and therefore needing more feed (Williams et al., 2006). It is not possible to draw far-reaching parallels between the British and the Swedish study, since the British chickens are reared in a completely different way to the Swedish chickens. For example, the British chickens are reared for a longer time and have therefore consumed significantly more feed per kg of meat at slaughter. Williams et al. (2006) also included buildings, etc. within the system boundaries and made assumptions concerning the nitrogen in manure that are not reasonable under Swedish conditions.

From a climate point of view, chicken and poultry meat seems to perform well compared with other types of meat. Poultry utilise feed efficiently and each breeding hen produces a large number of progeny, which means that the environmental impact from the mother is allocated among many chickens (Williams et al., 2006). Chickens, and also pigs, are primarily raised on grain and other feed which is produced on arable land. Beef and lamb are also reared on fodder from arable land, but largely on ley crops, which can have a positive effect on the organic matter content. Moreover, ruminants can utilise pasture land (see also the section *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*) and by-products (e.g. straw) from arable land. With this in mind, it is not possible to unilaterally recommend any livestock species without taking into account how it affects e.g. the use of land.

Lamb

No Swedish data were found on the climate impact and energy use of Swedish lamb and sheep rearing. In one study on the environmental impact of food production in England and Wales, primary energy use for conventionally produced sheep meat was 23 MJ and greenhouse gas emissions 17 kg carbon dioxide equivalents per kg of carcass weight (i.e. including bones) (Williams et al, 2006). For organic production the corresponding figures were estimated to be 18 MJ and 10 kg carbon dioxide equivalents, respectively. A difference between these systems is that the organic ley contains nitrogen-fixing clover and that less nitrogen fertiliser is used in the organic system. Sheep are ruminants and according to the IPCC guidelines for the calculation of greenhouse gas emissions, the methane production from sheep digestion corresponds to 8 kg of methane per animal and year (for sheep live weight 65 kg). This can be compared with 1.5 kg of methane from pigs and 57 kg of methane from cattle (cattle other than dairy cows in western Europe) (IPCC, 2006).

The study for England and Wales also compared the environmental impact of various livestock species (Williams et al., 2006). The results show roughly the same climate impact from beef as from sheep meat, but lower greenhouse gas emissions from pigs and poultry. The differences are explained by the fact that monogastric animals (pigs and poultry) grow more quickly, use feed more efficiently and each mother animal produces a large number of progeny per year (around 20-25 for sows and 250 for hens). However, ruminants (here sheep and cattle) can utilise other feeds, e.g. in the form of pasture and thereby contribute to keeping the landscape open (see also the section *A Rich Diversity of Plant and Animal Life*).

Game

A key difference between game animals and domesticated livestock is that the wild game would still exist even if it were not used as food. The environmental impact, e.g. expressed as carbon dioxide emissions, of the wild game would therefore be generated even if the meat were not used as food. Since much of the current focus is on reducing the anthropogenic (i.e. induced by humans) emissions of greenhouse gases, it is difficult to compare the climate impact per kg of meat from domestic animals and wild game without taking into account the origin of the animals, e.g. whether the game meat comes from free-ranging animals or animals reared in enclosures.

There are few studies of greenhouse gas emissions from game. In an earlier study from the Swedish Environmental Protection Agency, methane production from the digestion of feedstuffs of various animals was calculated (Murphy, 1992). Estimates included e.g. emissions from roe deer at around 7.6 kg of methane per animal and year. If the live weight is 22 kg and the dressing-out value is 45 per cent, these methane emissions are equivalent to 16 kg carbon dioxide equivalents per kg of meat (including bones). This does not consider the fact that the animal is often more than one year old at slaughter or the mother's methane emissions during pregnancy and lactation, which would result in greater climate impact from

the animal's entire lifetime. For moose, the methane emissions are reported to be around 60 kg per animal and year. With a carcass weight of 135 kg, this would be equivalent to 9 kg carbon dioxide equivalents per kg of meat (including bones), but also in this case the animal is normally more than one year old at slaughter and methane emissions from the whole of its lifetime are thereby higher. Estimates of methane emissions from reindeer are uncertain, but it is suggested that they are almost 50 kg carbon dioxide equivalents per kg of carcass weight. In the IPCC guidelines, methane emissions from deer are estimated at 20 kg per animal and year (live weight 120 kg) (IPCC, 2006).

Methane gas emissions per kg of game meat appear to be relatively high compared with those from meat from domestic animals. The fact that methane gas emissions make such a large impact is due to the relatively high methane emissions per animal and low carcass weight. Account also needs to be taken of the animal's age at slaughter in order to assess greenhouse gas emissions during the animal's whole lifetime. The relatively high methane emissions from the digestion of feedstuffs by game animals suggest that it is difficult to justify increasing the share of game meat in the diet through increased rearing in enclosures in order to thereby reduce the national emissions of greenhouse gases. However, it should be noted that the data on methane emissions from game are uncertain, and more detailed investigations are needed to give a clearer picture of the climate impact of game.

Slaughterhouse, Transport and Imports

The most energy use and the greatest climate impact of all meat production take place up to the farm gate (Johannisson & Olsson 1997; Amundsen & Thoresen, 1999; LRF, 2002). Beyond the farm gate, packaging, electricity use in the slaughterhouse and energy use by the household (transport from shop, storage and cooking) account for the largest energy uses (LRF, 2002). In a life cycle assessment of pig meat (from fodder production, rearing of pigs etc. to the plate), energy use in the slaughter house represented 10 per cent of the total energy use and 30 per cent of the total electricity use (LRF, 2002). The corresponding figures for chicken meat were 8 per cent and 25 per cent, respectively, and for beef 9 and 19 per cent, respectively.

When meat is imported, transport distances can be long and energy use considerable. If e.g. pork is imported from Denmark and transported by lorry 1 000 kilometres, the secondary energy use for transport is estimated at almost 2 MJ per kg of meat (excluding return trip by empty lorry) (Kumm & Larsson, 2007). The energy use for imported beef from Ireland (3 000 kilometres, only by refrigerated cargo ship) or Brazil (1 500 kilometres by truck and 12 000 kilometres by refrigerated cargo vessel) is estimated at around 0.6 MJ and more than 4 MJ per kg of meat, respectively (excluding empty return journey) (Kumm & Larsson, 2007). If the meat from Ireland were instead transported 3 000 kilometres by truck, the energy use would be 6 MJ per kg of meat (excluding empty return journey) (Kumm & Larsson, 2007). Energy use for the transport of meat can vary greatly between cases, since fuel consumption per kg of meat varies widely depending on different modes of transport, vehicle and how much of the

load capacity is used. Data on energy use for transport can be compared with the energy use up to the farm gate for Swedish pig production, being equivalent to around 15-20 MJ per kg of boneless and fat-free meat, while the figure for beef is 10-40 MJ (Tables 6.2 and 6.3).

The data in the literature suggest that the climate impact of Swedish meat production and rearing is not higher than in other countries, but rather lies at the lower end of the range (Tables 6.2 and 6.3). The literature also suggests that energy use for imports of meat is not negligible compared with the energy use required up to the farm gate (Tables 6.2 and 6.3). All in all, this suggests that it is difficult to justify that the share of imported meat for each type of meat should increase to reduce the climate impact from Swedish food consumption.

6.4 A Non-Toxic Environment

6.4.1 Milk

Table 6.4 summarises literature data from life cycle assessments of the use of chemical plant protection products in milk production.

Table 6.4. Use of chemical plant protection products in milk production (per kg ECM, unless otherwise specified)

Active substance (mg/kg ECM)			Reference	Comments
Herbicides	Insecticides	Fungicides		
51 (conv) 17 (org)	3.6 (conv) 2.7 (org)	4.1 (conv) 0.6 (org)	Cederberg et al. (2007)	23 dairy farms in northern Sweden. Conventional (conv) and organic (org) farms.
63 (conv h) 72 (conv m) 6.82 (org)	4.1 (conv h) 4.9 (conv m) 0 (org)	4 (conv h) 4.5 (conv m) 1.2 (org)	Cederberg & Flysjö (2004a)	23 dairy farms in south-west Sweden. Conventional and organic (org) production. The conventional farms were divided into high (conv h) and medium-high (conv m) production.
87	3.5	2.6	Cederberg & Flysjö (2004b)	Swedish milk production. Refers to use of plant protection products per litre semi-skimmed milk (1.5% fat)

A significant proportion of the diet of dairy cows comes from ley crops, which to a very large extent are cultivated without chemical plant protection products (refers to the growing crop) (Jordbruksverket & SCB, 2007b). However, it is common for glyphosphate to be used when the ley is terminated (i.e. when the grass ley is ploughed under) in conventional cultivation (Jordbruksverket & SCB, 2007a). By comparison, plant protection products are used on around four-fifths of the Swedish cereal acreage (SCB, 2007a). In the studies cited in Table 6.4, a large share of the use of plant protection products took place outside the farm in

connection with cultivation of feedstuffs (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). This use of plant protection products can among other things derive from cultivation of soya bean, which normally involves high use of chemical plant protection products (Cederberg & Flysjö, 2004a; Emanuelson et al., 2006; Rulli, 2007). In an earlier life cycle assessment of milk production on two Swedish dairy farms, soya bean production was calculated to account for three-quarters of insecticide use and 28 per cent of herbicide use up to the farm gate in conventional milk production (Cederberg, 1998). The soya bean was mainly imported from Brazil, and was cultivated using herbicides which are not permitted in Sweden, because of their potential to be carcinogenic (Cederberg, 1998).

The use of plant protection products varies significantly between different types of production and geographical locations (Table 6.4). Chemical plant protection products are used in conventional milk production, but are not permitted in organic crop production. In organic milk production, however, a small proportion of the fodder is allowed to be conventionally cultivated. Life cycle assessments of organic milk have shown that when plant protection products were used, they derive from purchased conventionally cultivated fodder (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). For organic production certified by KRAV, the regulations are gradually becoming stricter regarding the proportion of fodder allowed to be conventionally produced. From 2008, all feed for cattle must be organic, while up to five per cent of feed had previously been allowed not to be KRAV-certified (KRAV, 2007). In a comparison between organic milk production in northern and south-western Sweden, the use of plant protection products was higher on farms in the north. The farms in southern Sweden had greater access to organically produced protein feedstuffs (e.g. from field beans, peas and rapeseed), while the farms in the region of Norrland to a greater extent purchased feed from the feed industry, which generally used as much conventionally cultivated material as the regulations permitted (Cederberg et al., 2007). In conventional milk production the pesticide use up to the farm gate was slightly higher on farms in the south-west than in northern Sweden. Many of the conventional farms in Norrland used no pesticides on their own farm, while e.g. herbicide use was common at the termination of ley in southern Sweden (Cederberg et al., 2007).

Internationally, Sweden has a good status with regard to the risks of chemical plant protection products. This is due among other things to the strict approval process for new plant protection products, extensive work as regards safety and management issues and the generally low pressure of pests and diseases, which results in a relatively low need for control (Emanuelson et al., 2006). The literature suggests that a significant proportion of the use of plant protection products associated with Swedish milk production can be traced to imports of feed, including soya beans (Cederberg, 1998; Cederberg & Flysjö, 2004a; Cederberg et al., 2007). There is considerable potential to reduce the proportion of soya bean and the risks associated with the use of plant protection products, e.g. through a larger proportion of locally and regionally produced protein feeds such as rapeseed and stillage (a by-product from ethanol production) (Emanuelsson et al., 2006). From a financial perspective, however, it is difficult to exclude soya bean and other protein feeds which are imported from other continents in the short term. This is because the production costs for European protein feedstuffs are

higher and milk yield levels can be difficult to maintain, since the resulting concentrates are weaker with regard to content and quality of protein and energy (Emanuelson et al., 2006). The use of soya bean has nevertheless decreased from the second half of the 1990s, when consumption was very high due to protein overfeeding, which has now been corrected. According to the statistics of the Swedish Board of Agriculture, more than 200 000 tonnes of soya bean were imported for cattle feed in 1999 (Jordbruksverket, 2001), while the corresponding amount in 2006 was around 118 000 tonnes (according to correction of Table 1.2 in Jordbruksverket, 2007g). Systems for certification of more sustainable cultivation of soya bean and palm oil are also under development (Emanuelsson et al., 2006) (see also chapter 5 and sections 8.1 and 8.8.1).

6.4.2 Meat

Tables 6.5 and 6.6 show literature data from life cycle assessments on the use of plant protection products for beef and pig meat production. The pesticide use for the production of chicken meat is estimated in one life cycle assessment to be 760 mg of active substance of herbicides, 40 mg of insecticides and 6 mg of fungicides per kg of boneless and fat-free meat (LRF, 2002). Comparable figures for lamb and sheep production have not been found.

The use of chemical plant protection products varies greatly between different kinds of meat and between different studies (Cederberg & Darelus, 2000; LRF, 2002; Cederberg & Nilsson, 2004a; Cederberg et al., 2005; Kumm & Larsson, 2007). The differences depend for example on the choice of feed, and where and how the feed is produced. Cattle and sheep can be reared for the most part on pasture and roughage. Normally no or a small amount of chemical plant protection products are used on pasture land and in the cultivation of ley (except glyphosphate for the termination of ley) (Jordbruksverket & SCB, 2007a), so the contribution of this usage of plant protection products per kg of meat is relatively low where the animals are mainly reared on these forages (Cederberg & Darelus, 2000; Kumm & Larsson, 2007). When soya bean is included in the feed, a significant proportion of the use of plant protection products can often be associated with the cultivation of this soya bean (Cederberg & Darelus, 2001; Cederberg & Flysjö, 2004b; Kumm & Larsson, 2007). In a study of Swedish pig meat, one-third of the herbicide use and 90 per cent of the insecticide use derived from cultivation of soya bean (Cederberg & Darelus, 2001). The use of plant protection products per kg of meat is consequently greater where e.g. cattle are reared in a more intensive system with a greater proportion of feed concentrates such as grain and protein feeds (Cederberg & Darelus, 2000; Kumm & Larsson, 2007).

The amount of feed required for animals can vary according to animal type and rearing system. Consequently, the quantity of chemical plant protection products allocated per kg of meat can vary even when the use per tonne of feed is equal. Chickens and pigs are relatively efficient feed converters, which partly explains the lower use of plant protection products (measured as active substance) for chicken meat and pork than for beef (LRF, 2002). In a comparison between different rearing systems for pigs, the use of plant protection products (measured

as active substance per kg of meat) was lowest in the system in which feed consumption per kg of pork was lowest (Stern et al., 2005)

Table 6.5. Use of chemical plant protection products for beef production (per kg of boneless and fat-free meat)

Active substance (mg/kg ECM)			Reference	Comments
Herbicides	Insecticides	Fungicides		
1600 (dairy cows)	3.6 (conv) 2.7 (org)	4.1 (conv) 0.6 (org)	LRF (2002)	Swedish beef production from dairy cows. Includes meat from culled cows and rearing of bull calves as by-product from milk production.
2200 of which 99% herbicides (conv, dairy cows) > 0 (org, suckler cows) > 0 (org, dairy cows)			Cederberg & Darelius (2000)	Beef production from i) conventional young bulls from dairy cows (conv, dairy cows), ii) organic young beef animals from suckler cows (org, suckler cows) and iii) organic steers from dairy cows (org, dairy cows). Use of plant protection products specified as total quantity of active substance. Data from one farm in Halland, western Sweden.
0 (suckler cows)	0 (suckler cows)	0 (suckler cows)	Cederberg & Nilsson (2004a)	Organic beef production in ranch operation. Data from one farm in Skåne, southern Sweden.

There are several opportunities to reduce the use of plant protection products. In a study comparing the use and risks of chemical plant protection products in two future systems for cultivation of pig feed (Cederberg et al., 2005), the basic scenario generally corresponded to today's cultivation system and a large proportion of the protein feed was assumed to be imported. In the other scenario the focus was on reducing the environmental load from pig production, for example through a greater proportion of home-grown protein feed and measures to reduce the use of plant protection products. These measures were estimated to halve the use of pesticides on the farm, or reduce it by 60 per cent when reduced imports of protein feed were included, without energy use and leaching of plant nutrients being adversely influenced (Cederberg et al., 2005).

Even though the use of plant protection products is low on Swedish farms and there are systems to reduce the risks posed by this use, imported feed can lead to risks associated with the use of plant protection products in other parts of the world. Having a larger proportion of organically cultivated feedstuffs, locally or regionally produced feedstuffs or feedstuffs produced according to certification systems for enhanced sustainability are three possible strategies for reducing these risks (Emanuelsson et al., 2006). No or low use of pesticides can also benefit biodiversity.

Table 6.6. Use of plant protection products in pork production (per kg of boneless and fat-free meat)

Active substance (mg/kg ECM)			Reference	Comments
Herbicides	Insecticides	Fungicides		
900	50	180	Cederberg & Dareljus (2001)	Data from an integrated piggery in Halland, western Sweden.
0-170	0-1,5	0-1.2	Cederberg & Nilsson (2004b)	Model. Two farms for organic pig production in Sweden.
770	20	60	LRF (2002)	Data from two Swedish conventional farms.
550 (A) 490 (B) 1200 (C)	47 (A) 46 (B) 62 (C)	60 (A) 87 (B) 210 (C)	Cederberg & Flysjö (2004b)	Model. Three future pig production systems in Sweden. The scenarios focus on animal welfare (A), environment (B) and high product quality at low cost (C).
Total of:	2700 (conv) 480 (org) 2900 (red label)		Basset-Mens & van der Werf (2005)	Three French production systems: conventional (conv), organic (org) and standardised quality label (red label). ¹

¹ Data given per kg of pork. It was assumed that dressing-out percentage was 50 per cent for conversion to boneless and fat-free meat. Use of plant protection products is given as total quantity of active substance.

6.4.3 Veterinary Medicines

In an international perspective, Sweden has a good animal health situation and many of the diseases that occur in other countries do not occur at all or only occasionally in Sweden (SVA, 2007a). Salmonella is found only a few times in Swedish food producing herds each year. More than 80 per cent of the Swedes who contract salmonella poisoning become infected abroad (Jordbruksverket & SCB, 2007b). According to Swedish zoonose legislation, suspected salmonella infection in animals is notifiable (SVA, 2007b). In a comparison of beef from Sweden and Brazil, it was found that Brazilian young cattle can be de-wormed up to 12 times per year, while Swedish young cattle are de-wormed once or twice during their first grazing period (Kumm & Larsson, 2007). Parasites survive and breed more rapidly in the warm climate in Brazil, and climate-related stress can also make grazing animals less resistant to parasite infection.

In Sweden the use of antibiotics is covered by a comprehensive regulatory framework and antibiotics for animals are only permitted on prescription from a veterinary surgeon. The purpose of the legislation is to avoid pharmaceutical residues in food and to avoid genetic resistance to antibiotics being developed and spread (SVA, 2007a; Nordlander et al., 2007). More resistant bacteria mean that medicines lose their effect and the treatment of diseases becomes more difficult. Use of antibiotics in Swedish herds has decreased in recent years, and more than 80 per cent are used for the treatment of individual animals. Since 1986,

antibiotics have not been allowed to be routinely mixed into feed to increase animal growth in Sweden. These regulations also apply in the EU since 2006 (Nordlander et al., 2007; SVA, 2007a). According to an EU council directive (96/22/EC), hormones are not permitted for growth promoting purposes in animal production (Nordlander et al., 2007). However, in many countries outside the EU, antibiotics or hormones are used to promote animal growth (EFSA, 2007; SVA, 2007a).

In the Swedish National Food Agency's latest inspection of residues, including antibiotics and hormones, in Swedish production of live animals and animal foodstuffs, antibiotic residues exceeded the limit in only four of 9 000 samples (Nordlander et al., 2007). Quantifiable quantities of narasin (mixed into feed to control parasites) were also found in a few samples of eggs. Narasin is permitted for use in chickens, but not in hens, but the feed for chickens and hens is produced in the same factories. The feed industry is working to prevent hen feed becoming cross-contaminated. The proportion of positive samples from eggs has sharply decreased in recent years. In the samples analysed, no growth-promoting synthetic substances or abnormal levels of hormones were found (Nordlander et al., 2007).

National measurements of residues in live animals and animal foodstuffs are compiled in the EU. The latest report presents values for 2005. The contents of antibiotics ('antibacterials') exceeded the permissible limits ('non-compliant results') in 0.20 per cent of all samples, which can be compared with 0.22 per cent in 2004. As regards hormones, 0.44 per cent of samples taken from pigs and 0.13 per cent of samples from cattle had levels which exceeded the permissible limits, which represented increased levels compared with 2004. The results also showed that the limits were exceeded in some cases for veterinary medicines, heavy metals, etc. However, in these compilations it is not possible to distinguish results from individual member countries (Commission of the European Communities, 2007).

The favourable animal health situation in Sweden, the country's restrictive use of veterinary medicines and the low incidence of residues in Swedish animal products suggests that the use of veterinary medicines and the risk of residues is relatively low in Sweden from an international perspective. Continued preventative work is one prerequisite for maintaining this situation.

6.5 A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

The environmental objective *A Varied Agricultural Landscape* concerns animal production to a very large extent. The interim targets that relate to animal production are primarily interim target 1 on the management of meadows and pasture (Jordbruksverket, 2003a; Plateryd, 2004) and interim target 4 on preservation of plant genetic resources and indigenous livestock breeds. Interim target 1 states that the area of traditionally managed meadow land and the most endangered types of pasture land (among others pasture in Norrland, *alvar*, summer mountain grazing and forest pastures) should increase. As regards

indigenous livestock breeds, it has been concluded that there are not enough individuals of all species in order to ensure preservation (Jordbruksverket, 2007f; Naturvårdsverket, 2007). This applies especially to endangered poultry breeds (Naturvårdsverket, 2007).

This section mainly discusses pasture and arable land and how Swedish animal production can contribute to preserving these resources. Much of the biodiversity in the agricultural landscape can be linked to meadows and permanent pasture (Jordbruksverket, 2003a). In general, biodiversity benefits from organic production, which is explained by a more diversified crop rotation and no use of chemical plant protection products (Drake & Björklund, 2001). Links between the condition of arable land and animal production primarily concern feed production and the content of plant nutrients in manure, organic material and undesired substances such as heavy metals in the manure. Plant nutrient issues are discussed more closely in the section *Zero eutrophication and plant nutrient flows*. The section also discusses the total land use for animal production, including land for the cultivation of feed crops in other countries.

The structural changes that have taken place in Swedish agriculture during the last hundred years have included increasing specialisation in the agricultural businesses, including purely arable enterprises and more specialised livestock enterprises. Specialisation has among other things been driven by increased access to cheap mineral fertilisers after the Second World War and by the demand for rationalisation and increased production levels (Claesson & Steineck, 1991). Increased access to mineral fertilisers has resulted in farming enterprises not being as dependent on farmyard manure from livestock to manage crop production. The structural changes have also led to animal production being concentrated towards certain regions and to large livestock units (SCB, 2000; Jordbruksverket, 2007b). The proportion of large arable farms is e.g. high around Lake Mälaren, while a large proportion of animals are found in western Sweden and Skåne (Jordbruksverket & SCB, 2007b). This has resulted e.g. in an uneven distribution of farmyard manure in the country and in feed being transported from regions with many crop production enterprises to more intense livestock areas (Claesson & Steineck, 1991; SCB, 2000).

6.5.1 Conservation of Pasture Land

The operational changes and the economic conditions have also meant that the need for meadow and natural pasture has decreased sharply (Jordbruksverket, 2003a; Plateryd, 2004). Leys have instead increasingly greater significance for roughage production and as pasture (SCB, 2000; Jordbruksverket, 2003a). Estimates suggest that there were around 2 million hectares of meadow and rough grazing in Sweden around a hundred years ago (SCB, 2000). Today there are about 500 000 hectares of rough grazing and 8 000 hectares of meadow land remaining, and these pieces of land are less connected than before (Jordbruksverket, 2003a; Swedish Environmental Protection Agency, 2007; Jordbruksverket & SCB, 2007b). The fragmented landscape and the reduced acreage can make conserving the biodiversity of rough grazing difficult (Jordbruksverket, 2003a). The conditions for conserving pasture land can also be

affected by fewer grazing animals (Jordbruksverket, 2003a). The number of dairy cows has decreased in recent years, while the number of sheep and suckler cows has increased. There are more than 280 000 horses in the country (Jordbruksverket & SCB, 2007b), which may partly compensate for the decreased number of cattle. However, horses are primarily concentrated to peri-urban areas and are not likely to replace other grazing animals outside peri-urban areas to any great extent (Jordbruksverket, 2007f). Moreover, the number of cattle herds has decreased sharply in recent years (Jordbruksverket & SCB, 2007b), which can result in longer distances between the animal herds and pasture, making the work of keeping pasture open more difficult and costly (Jordbruksverket, 2007f). In 2006, there were just over 25 000 cattle herds, in contrast to more than 47 000 herds in 1990 (Jordbruksverket & SCB, 2007b).

Grazing animals such as cattle and sheep, and proper management, such as appropriate grazing pressure and moderate clearing of grazing land, are very important means of conserving the value of natural pasture grounds (Jordbruksverket, 2003a; Plateryd, 2004). This requires active agriculture and grazing animals where the pasture is located. Some of the most endangered types of pasture in Sweden consist of *alvar*, summer grazing in mountain areas and forest pastures, as well as pasture land in Norrland. Increased milk consumption or greater consumption of Swedish beef and sheep meat will not automatically support pasture land, however, since many animals graze on more energy-rich arable leys or are reared on feed other than pasture. Lambs are normally around 6 months at slaughter and are reared with different feeding strategies depending on when they are born during the year. A large proportion of the feed for spring lambs consists of pasture, while lambs born in the winter are normally reared more intensively and are slaughtered before the grazing season (Andréasson & Sundelöf, 1999).

Nationally there is no true shortage of grazing animals. The problem is more related to the uneven distribution of animals between the regions and between farming enterprises, which can make the ability to preserve pasture land difficult in individual areas (Jordbruksverket, 2007f; 2007h). Efforts may also be needed to ensure that grazing animals graze on natural permanent pasture instead of arable leys (Jordbruksverket, 2007f; 2007h). In addition, there may be great opportunities to use grazing animals more efficiently. A reduction in the number of grazing animals in one area does not automatically lead to reduced acreage of actively grazed pasture (Jordbruksverket 2007h). The Swedish Board of Agriculture has calculated that there are on average 0.79 animal units of grazing animals available per hectare of pasture in Sweden (Jordbruksverket, 2007h). The number of animal units that can graze a hectare of pasture land varies greatly depending on e.g. the yield of various types of pasture land. If one assumes that 0.7 animal units of grazing animal per hectare (corresponds to the mean of moderate/normal to wet pasture land) functions as an average indicator of appropriate grazing pressure, a quarter of Sweden's municipalities fall under this limit and consequently may have difficulties in maintaining pasture land. However, this includes municipalities with predominantly dry pasture with low yield, and maintenance can therefore be accomplished with significantly fewer grazing animals.

One way to promote the conservation of natural pasture is to choose meat from animals that have grazed entirely or partly on such lands. Since the pasture land is located in the entire country, it is also important that grazing animals exist throughout the whole country and that they are used to maintain natural pasture. So-called naturally grazed meat is now commercially available and is often marketed using a name associated with the district where the animal was reared (Plateryd, 2004). In addition, the energy and resource use can be very low in unfertilised pasture-based systems (Cederberg & Dareljus, 2000; Cederberg & Nilsson, 2004a). This is further argument for prioritising pasture-based meat from cattle and lamb over beef and lamb meat from animals which are primarily reared on concentrates or other cultivated feedstuffs.

6.5.2 Production Capacity of Arable Land

Some of the characteristics that describe the condition of arable land and its production capacity are organic matter content, plant nutrient availability, pH, structure and texture. Organic matter originates from dead plant and animal parts. High organic matter content contributes among other things to good soil structure and good soil water-holding capacity (Claesson & Steineck, 1991). The soil structure affects soil production capacity to a large degree, e.g. the risk of soil compaction and how easily roots can penetrate the soil (Claesson & Steineck, 1991).

There are no conclusive data on how different types of farming affect soil properties. This is because type of farming is largely dictated by the local climate and soil type and it is therefore difficult to determine whether the soil properties are due to the type of farming or the local conditions (Eriksson et al., 1997). In a survey from the end of the 1990s on the condition of Swedish arable land, the organic matter content of the soil tended to be higher on farms with cattle than crop production and pig farms (Eriksson et al., 1997). An important difference between the types of farming is that the cattle farms cultivate a lot of ley. Ley cultivation has a positive effect on organic matter content, since the soil is covered for a long time and is not tilled as often (Eriksson et al., 1997). As regards the occurrence of heavy metals, analyses show that the zinc and copper contents in the soil tend to be higher on pig farms than on livestock and arable farms. This is explained by the fact that zinc and copper are added to piglet feed in order to prevent diarrhoea during weaning (Eriksson et al., 1997).

Organic cultivation can benefit soil structure, biological activity and organic matter content (Drake & Björklund, 2001). In organic cultivation, ley and green manure crops are important elements for e.g. nitrogen supply. Ley cultivation is also important in the conventional production of ruminants. Cultivation of these crops can have a positive effect on the production capacity of arable land. In long-term trials, organic farming based on closing cycles with a high proportion of ley in the crop rotation was shown to increase the organic matter content of the soil (Kjellenberg & Granstedt, 2005).

Soil compaction is one of the greatest threats to the production capacity of arable land (Naturvårdsverket, 2007). One way to reduce the risk of soil compaction is to

cultivate leys or other crops that benefit soil structure. Ley has a large root volume, leaves large quantities of crop residues and keeps the soil covered for several years, which contributes to improved soil structure. However, it is important to avoid damage during harvesting of the ley, since the traffic that occurs during ley harvesting is often intensive (Claesson & Steineck, 1991; Håkansson, 2000).

With regard to the food producing capacity of Swedish arable land, increased ley cultivation, e.g. for feeding cattle and sheep, can contribute to improved soil structure. This applies especially in areas with weak-structured soils and a high proportion of cereals or other annual crops. One example is Västerås, where a biogas facility which is fed with ley crops has been built. The reason for using ley crops is to improve soil structure through increased ley cultivation and recycling of an organic fertiliser in the form of biodigestate to the fields (Vafab, 2007). In districts with a lot of ley cultivation, for example in Norrland and in the forest counties of Sweden, increased feed production through cultivation of cereals and other annual crops can improve the degree of self-sufficiency, contribute to keeping arable land open and constitute a positive element in the crop rotation (Cederberg et al., 2007).

6.5.3 Land Use

Land is a finite resource which should be used in a resource-efficient way in order to produce enough food, fuel and fibre in both the long-term and short-term. At the same time, soil fertility, biodiversity and preservation of cultural values and an open landscape are important aspects of sustainable land use that are dealt with in the national environmental quality objectives. In this context, large land use per kg of agricultural product is not necessarily negative. Erosion, loss of biodiversity and other forms of soil degradation constitute severe global threats to production capacity and soil fertility (Steinfeld et al., 2006). This section discusses how animal production can contribute to more efficient land use and preservation of the land's values.

In an international perspective, land use for milk production is relatively large in Sweden. Contributory causes are differences in climate and the fact that a larger acreage is needed to produce the same quantity of feed (Cederberg et al., 2007). According to life cycle assessments of milk production in Sweden, land use per kg of milk is higher in the north than in the south of Sweden. Contributory factors were lower yields in northern Sweden and the previous system of environmental subsidies to farmers, which promoted high home-grown ley cultivation per cow in northern Sweden (Cederberg et al., 2007). High land use in northern Sweden is regarded as positive, since the alternative can be afforestation and thereby adverse impacts on the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life* (Cederberg et al., 2007).

In meat production, land use is in general lower per kg of pig meat and chicken meat than per kg beef and sheep meat (LRF, 2002; Williams et al., 2006). Pigs and especially chickens are efficient feed converters. In addition, each mother animal produces many offspring, which means that feed is not needed for as many

mothers. On the other hand, cattle and sheep, in contrast to pigs and chickens, can utilise land which cannot be used for other purposes and contribute to keeping pasture land open. In the case of high ley yields, land use by ruminants is comparable to that by monogastric animals. Moreover, ley cultivation can be positive for preserving the production capacity of arable land. However, the total land use for different types of animals can vary significantly depending on the rearing system and choice of feed. Extensive rearing of cattle with large proportions of natural pasture or grazing on arable land contributes to high land use per kg of meat. At the same time there is added value in keeping pasture land open. Moreover, land use is generally higher per kg of meat or per litre of milk in organic production (e.g. Cederberg & Dareljus, 2000; Cederberg & Flysjö, 2004a; Cederberg et al., 2007). Compared with average conventional yields in Sweden, yield levels per hectare are lower in organic production (Jordbruksverket & SCB, 2007b).

Imports of feed or meat can lead to adverse effects in other countries. One example is erosion, which in a global perspective is a relatively small problem in Sweden, but a serious threat in many other countries. Erosion is an irreversible process which contributes to large areas of arable land being lost annually. In a comparison between different protein feeds, the soil erosion associated with Swedish rapeseed cultivation was calculated at 0.03-0.05 tonnes of soil per hectare and year while corresponding losses were about 8 tonnes for soya bean cultivation in Brazil and 7.7-14 tonnes for oil palm cultivation in Malaysia (Bertilsson et al., 2003).

Converting rainforests and other land into farming of e.g. soya bean and oil palm also results in loss of biodiversity, since rainforests are very species-rich (Emanuelson et al., 2006; Steinfeld et al., 2006). Deforestation is also a major source of greenhouse gas emissions from animal production (Steinfeld et al., 2006).

Soya bean and palm kernel expeller account for a significant proportion of protein feed for Swedish livestock (Jordbruksverket, 2007g). By increasing the proportion of locally and regionally produced protein feed such as peas or by-products from oilseed crops and sugar beet, the negative environmental impact from erosion and deforestation, etc. by Swedish livestock production can be reduced. A combination of animals that are efficient feed converters (e.g. pigs and chickens) and animals that graze on natural pasture is positive for conserving the value of the landscape and contributes to efficient land use.

6.6 Zero Eutrophication and Plant Nutrient Flows

6.6.1 Plant Nutrient Balances

Plant nutrients are mainly supplied to the soil via manure, mineral fertilisers or other added fertilisers. Nitrogen is also supplied through nitrogen deposition and via nitrogen-fixing bacteria, which capture nitrogen from the air. These bacteria live in symbiosis with e.g. clover, peas and other legumes. Plant nutrients in manure are derived from the feedstuffs. Import of plant nutrients via purchased

feedstuffs can be significant. A difference between organic and conventional agriculture is that organic production is based more on recycling the plant nutrients in the system and capturing nitrogen via leguminous plants. The same principles are applied in conventional production, but it can also be supplied and supplemented with purchased mineral fertilisers.

In a plant nutrient balance, all plant nutrient flows e.g. within a farm are compiled. The resulting balance indicates e.g. whether the supply of plant nutrients is greater than the removal, or the proportion of added plant nutrients found in products leaving the farm (nutrient use efficiency). In this section, plant nutrient balances are discussed first and foremost in order to focus on nitrogen and phosphorus as resources and opportunities to make the use of these resources more efficient. As long as the supply of nitrogen and phosphorus is within reasonable intervals, it is not possible to use plant nutrient balances to determine how large plant nutrient losses are e.g. in terms of leaching. Individual events and other factors (e.g. high runoff or tillage) may affect leaching to a greater extent (Ullén et al., 2004).

Farms with animals generally utilise nitrogen less well than arable farms. This is mainly due to losses of ammonia from the storage and handling of manure (Claesson & Steineck, 1991). Ammonia losses depend among other things on how the manure is stored and when and how it is spread. The losses are generally lower from storage of liquid manure than from storage of solid manure. Some strategies to limit the losses when spreading are rapid incorporation of the manure, little surface contact with the air and avoiding spreading in warm and windy weather (Claesson & Steineck, 1991; Cederberg et al., 2007).

The problems associated with nitrogen losses from manure concern all animal production, irrespective of whether the production is organic or conventional. However, the amount of nitrogen in the system can vary between different types of farming and forms of production. Comparing organic and conventional milk production, the nitrogen surplus is higher per hectare on conventional farms (Cederberg & Flysjö, 2004a; Cederberg et al., 2007). The supply of nitrogen (via mineral fertilisers and feed) is greater per hectare in the conventional system, but the production is also higher in the conventional system. When the nitrogen surplus was allocated per tonne of milk there was no significant difference between the farms in south-west Sweden, while the surplus was significantly lower on the organic farms in the Norrland study (Cederberg & Flysjö, 2004a; Cederberg et al., 2007).

Phosphorus mineral is a finite resource, and high supply of phosphorus can lead to resource waste, especially if the land is taken out of food production. Estimates of phosphorus balances show that the net supply of phosphorus is greater on pig farms than on arable and cattle farms, a difference explained by large import of phosphorus through feed to pig farms (Eriksson et al., 1997). On the farms sampled in that study, animal density was also higher on pig farms than cattle farms (Eriksson et al., 1997). In comparisons between organic and conventional milk production, the supply of phosphorus per kg of milk is reported to be significantly higher in conventional production (Cederberg & Flysjö, 2004a; Cederberg et al., 2007), due to more purchased feed and use of mineral fertilisers on the conventional farm.

6.6.2 Zero Eutrophication

Emissions of eutrophying substances generate different effects depending on where they are released. In the Baltic Sea, emissions of phosphorus need to be addressed first and foremost, while on the Swedish west coast it is considered more important to prioritise measures that limit the supply of nitrogen (Naturvårdsverket, 2007). Emissions of eutrophying substances from agriculture are a minor problem in the north of Sweden. This is because among other things of the smaller share of agricultural land and colder climate, which contribute to less leaching. Moreover, a proportion of the plant nutrients that are leached from arable land are removed from the water by retention. This occurs through denitrification (nitrates converted to nitrogen or nitrous oxide), sedimentation or uptake by plants. Retention contributes to only 10-20 per cent of the nitrogen that leaches from arable land in the inland highlands of Småland reaching the sea, while the corresponding figure for coastal arable land can be up to 90 per cent (Jordbruksverket & SCB, 2007b).

Nutrient leaching is also affected by natural and cultivation factors. For example, the risk of nitrogen leaching is higher from sandy soils than from clay soils. In addition, leakage is influenced by the crops grown and by tillage. Tillage stimulates the breakdown of organic material in the soil and can thereby increase the risk of nitrogen leaching. The termination of leys can e.g. cause a high risk of leaching. In life cycle assessments, a eutrophication potential is often indicated, i.e. a worst case scenario in which all eutrophying emissions of nitrogen and phosphorus reach water courses and cause eutrophication. In practice, the impact is seldom so severe.

Agriculture accounts for half the net load of nitrogen to the sea (i.e. after retention has been taken into account) (Jordbruksverket & SCB, 2007b). According to life cycle assessments, a large proportion of emissions of eutrophying substances from meat and milk production take place up to the farm gate and in the form of nitrogen leaching from arable land and ammonia emissions from manure (e.g. LRF, 2002; Cederberg & Flysjö, 2004a; Cederberg et al., 2007). Ammonia emissions vary widely between different management and spreading systems for manure. Ammonia emissions are greater in loose houses than in tied-stall houses. In manure storage, the losses are lower from liquid manure than from solid manure and deep litter manure (Cederberg et al., 2007). Life cycle assessments also suggest that the eutrophication potential is higher per kg beef than per kg pig meat and poultry meat (e. g. LRF, 2002; Williams et al., 2006; Tynelius, 2008), which is partly explained by the fact that land use is higher per kg beef than per kg pig and poultry meat, and partly by the fact that there is more nitrogen (which can generate ammonia) in the manure generated per kg beef than per kg pig and poultry meat.

When organic and conventional production are compared, calculations suggest potentially higher emissions of eutrophying substances per kg organic meat or milk (Cederberg & Dareljus, 2000; Cederberg & Flysjö, 2004a; Cederberg et al., 2007). One explanation is that the land use is greater per kg of meat or milk, but

the results are uncertain because the models and emission factors used to calculate nitrogen leaching do not take account of differences in the type of production (Cederberg et al., 2007). There is also a lack of data when it comes to nitrogen losses linked to legume crops, which are an important source of nitrogen in organic production. Nitrogen losses can also be considerable when ley is terminated.

Efficient use of plant nutrients is advantageous from a resource point of view, e.g. by spreading the quantity manure needed and where it is needed. Small ammonia emissions, e.g. through well-designed manure storage facilities, also decrease the contribution of eutrophying substances.

6.7 Discussion and Conclusions

6.7.1 Impacts of Animal Production on the Environmental Quality Objectives

The largest proportion of environment impact occurs before the farm gate (LRF, 2002), and certain environmental quality objectives such as e.g. *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life* that include animal production primarily concern production up to the farm gate. The focus in this section is therefore on production up to the farm gate, but as for other food groups, there is an environmental impact of transport, processing, freezing, etc. at later stages of the food chain.

Reduced Climate Impact

Overall, methane and nitrous oxide account for a relatively large proportion of the climate impact of animal and milk production.

Climate impact is estimated to be lower per kg of meat from pigs and poultry than from cattle and sheep. The differences are e.g. because monogastric animals (pigs and poultry) grow more quickly and use feed more efficiently and that each mother animal produces a large number of progeny per year (around 20-25 for sows and 250 for hens, compared with 1 for cows and 1-3 for ewes). A large number of progeny means that the climate impact of the mother is allocated among many individuals and therefore each of the progeny carries less climate impact. In addition, the methane from the animal's digestion of feedstuffs accounts for a large part of the climate impact of ruminants (cattle and sheep), but a very small proportion of the climate impact of monogastrics. On the other hand, ruminant feed, unlike the feed for monogastric animals, can be based on ley and pasture to a large extent. Ley cultivation and grazing on permanent pasture and long-term leys has positive effects on several environmental quality objectives. As regards climate impact from game meat the data are uncertain, but they suggest that methane emissions from e.g. deer, roe deer, reindeer and moose may be significant. Free ranging game are a special case, since the animals would exist and affect the environment even if the meat were not used as food.

As regards beef, some studies suggest that the climate impact of beef from dairy cow breeds is slightly lower than that from beef breeds. This is because the climate impact from dairy cows can be allocated between the milk and beef products, while the impact from beef cattle is carried completely by the meat production. From a climate point of view, the literature does not provide clear-cut support for advocating either organically or conventionally produced beef, but the number of studies is limited. From a climate point of view, Swedish beef production seem to compare relatively well in an international perspective, but there are few comparable studies. Increasing the proportion of imported beef instead of Swedish beef production is consequently difficult to justify from a climate perspective. As regards the climate impact of meat production from sheep and lamb, there are few studies available. In a study from England and Wales in which the environmental impact from various types of livestock were compared, the results showed a fairly similar climate impact per kg of beef and sheep meat (Williams et al., 2006).

As regards pig and chicken rearing, feed production (i.e. cultivation, transport, storage and processing if any) accounts for a large proportion of the climate impact. Using feed with little climate impact is therefore an important strategy for limiting emissions of greenhouse gases from this form of animal production. It is also important that the feed can be used efficiently, e.g. through the amino acid composition in the feed being well adapted to the requirements of the animals. This is more difficult to achieve in organic production if the same high yield as in conventional production should be attained. This is rather a question of what intensity is appropriate in the production. The total emissions of greenhouse gases per kg of pork appear not to differ much between the studies reviewed in this report. Consequently, from a climate point of view, there is nothing that clearly indicates that the proportion of pork of any particular origin or from any particular form of production should change to reduce the climate impact from Swedish pig meat consumption. As regards chicken and poultry meat, there are very few studies in which different forms of production or types of farming are compared.

As regards milk, high-yielding cows are estimated to emit more methane per animal and year than low-yielding cows, but when the methane emissions are allocated per litre of milk the emissions are lower (Cederberg et al., 2007). From a climate point of view, the literature gives no clear-cut support for advocating organically or conventionally produced milk, nor are there clear-cut differences in climate impact between milk production in north and south-west Sweden, but the number of studies are limited (Cederberg et al., 2007). The distribution of greenhouse gases can differ between different types of farming and regions, however. In organic production methane may account for a larger proportion of greenhouse gas emissions, because of these cows yielding slightly less milk and their food can include a larger proportion of roughage, which can contribute to more methane being emitted during the digestion of feedstuffs. In conventional milk production, nitrous oxide accounts for a greater share of the climate impact, which can be derived from the manufacture of mineral nitrogen fertiliser and greater nitrous oxide emissions from arable land.

Energy use for transportation, e.g. for import and distribution of meat, is affected to a large degree by mode of transport, the capacity of the vehicles and the vehicle fill rate, but also depends on transport distance. For example, the energy use per tonne and kilometre is greater for transport by lorry than by ship. The literature suggests that energy use for imports of meat is not negligible compared with energy use before the farm gate. Bearing in mind that Swedish animal and milk production also seem to perform well in international comparisons, an increased proportion of imports may be difficult to justify from a climate and energy point of view.

There is research suggesting that the turnover of carbon in the soil and changes in the organic matter content may have great significance for total greenhouse gas emissions from the entire life cycle of the animal production. The organic matter content is maintained by addition of organic material, e.g. from farmyard manure. In addition, ley farming, e.g. for feed production for beef cattle and sheep, has a positive effect on the organic matter content since the soil is covered for a long time and it is not tilled as often (Eriksson et al., 1997). The organic matter content also concerns other environmental quality objectives such as *A Varied Agricultural Landscape*. Organic production is advantageous in this regard since a lot of ley and manure is used, which also favours the organic matter content.

A Non-Toxic Environment

The use of plant protection products varies to a large extent between different forms of production. Use of plant protection products is negligible in organic animal production. In life cycle assessments of organic milk and meat products, any use of plant protection products may derive from the proportion of the purchased feed that is allowed to be conventionally cultivated. For organic production certified in accordance with KRAV regulations, the amount of feed that is allowed to be conventionally produced is gradually being lowered. As consumers we can reduce the use and risks of plant protection products by choosing meat and milk that is organically produced.

Plant protection product use also varies between different feed products. In Sweden, normally no or a small amount of plant protection products are used on pastures and ley crops (refers to the growing crop), but glyphosphate is often used in conventional cultivation when terminating ley. In the case of conventional cultivation of cereals and protein feeds, a large proportion of the arable land is normally sprayed. Having a large proportion of locally/regionally or organically cultivated fodder is another possible strategy to reduce the use and risks of chemical plant protection products.

The literature suggests that efficient use of feed can restrict the need for of plant protection products, in terms of grams of active substance per kg of meat. For example the use of plant protection products may be higher in conventional rearing of cattle than chicken and pigs. An explanation is that chickens and pigs are more efficient converters of feed. However, use of plant protection products however varies depending on which feed is used and how the constituent feedstuffs are cultivated.

The literature suggests that the use and risks of veterinary medicines are relatively low in Sweden from an international perspective. However, no account has yet been taken of the potential risks of pharmaceutical residues ending up in the soil or water. Sweden has a good animal health situation and many of the diseases which occur in other countries seldom or never occur in the country. The use of veterinary medicines is controlled by a comprehensive set of regulations that aim to prevent pharmaceutical residues occurring in food and the development and spread of antibiotic resistance. The incidence of pharmaceutical residues in Swedish animal products is low. Preventative work is one of the prerequisites for this situation to be maintained.

A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

Several of the interim targets under these environmental quality objectives relate in the first place to agriculture. Agriculture has the ability to attain these environmental objectives. Regarding animal production, this applies especially as regards the conservation of pasture land.

Much of the biodiversity in the landscape can be linked to natural pasture and meadows. However, their area has decreased sharply as a consequence of changes in the type of farming and poorer economic conditions, and they have been increasingly split up. Ley has instead gained greater significance for pasture and production of roughage. In order to preserve natural pasture land and its values, grazing animals such as cattle and sheep are needed. However, there are many parameters that affect how many grazing animals are needed nationally to preserve meadows and pasture land, e.g. geographical distribution of animals, how large a share of the feed is comprised of natural grazing and pasture production level.

As consumers, we can encourage from the conservation of natural grasslands by choosing meat from animals that entirely or partly graze on such pastures. Naturally grazed meat from Swedish herds is now commercially available. Choosing locally and regionally produced naturally grazed meat contributes to conserving pasture land in the region and can reduce transport needs. However, consumption of Swedish milk or Swedish beef and sheep meat does not automatically mean that natural pasture is managed, since many animals graze on more energy-rich ley on arable land or are reared with feed other than pasture. Lambs that are reared in spring are e.g. to a great extent fed by grazing on arable leys, while winter lambs are normally reared more intensively (with cereals and stored fodder) and slaughtered before the grazing season. Energy and resource use can be very low in pasture-based and unfertilised systems, which is further reason for prioritising pasture-based beef and sheep meat over meat from animals primarily reared on concentrates or other cultivated fodder.

Agricultural land is also a limited resource that should be used resource-efficiently and in a way that maintains its value so that it can produce sufficient amounts of food, fuel and fibres in both the short and long term. Large land use per kg of agricultural product is not necessarily negative, however, since land use can

contribute to preserving cultural values and an open landscape. By choosing meat from pigs and chickens instead of beef or sheep meat, the total land use can be kept down.

Imports of feedstuffs or meat can lead to adverse effects in other countries. For example, erosion is a small problem in Sweden, but a serious threat in many other countries. Converting rainforests and other land into farming of e.g. soya bean and oil palm also results in loss of biodiversity, since the rainforests and the *cerrado* are very species-rich. Soya bean and palm kernel expellers account for a significant part of protein for Swedish livestock. With a larger share of locally and regionally produced protein feed (e.g. peas and rapeseed), the adverse environmental impact of livestock production as a consequence of erosion and deforestation in other countries can be decreased.

A combination of animal products from animals that are efficient feed converters (e.g. pigs and chickens) and from animals that graze on natural grassland and permanent pasture is favourable for preserving the land's value and contributes to efficient land use.

Zero Eutrophication

A large proportion of the emissions of eutrophying substances from animal production occur in the form of nitrogen leaching from farmland and ammonia emissions from manure. Ammonia emissions are affected to a large degree by how the manure is stored and spread. Ammonia emissions in storage are e.g. lower from liquid manure than from solid or deep litter manure.

The literature suggests that total emissions of eutrophying substances can be higher per kg of beef than per kg of pig and poultry meat, and higher for organically than conventionally produced milk and meat (expressed per kg product). This is due to greater land use per kg of beef and per kg organically produced product, respectively. As regards organic production, the results are uncertain, however, since the models and emission factors which are used in the reported life cycle assessments do not take account of differences in types of farming.

6.7.2 Imports or More Local Production

The literature provides support for Swedish animal and milk production from an environmental point of view. Swedish production performs well in international comparisons e.g. with regard to *Reduced Climate Impact* and *A Non-toxic Environment*. For example, the climate impact of Swedish milk production (up to the farm gate) appears to be lower or comparable to that of milk production in some other countries. If transport is also added for imports of milk and meat, animal foodstuffs produced in Sweden appears even favourable. High milk yield per cow and relatively low use of mineral fertilisers contribute to keeping down greenhouse gas emissions per litre of milk (see e.g. Cederberg & Flysjö, 2004a; Elmquist & Mattson, 2005; Cederberg et al., 2007). There are also significant

opportunities for improvement e.g. by reducing the proportion of soya bean in the feed and instead increasing the proportion of locally or regionally produced protein feed (e.g. rapeseed and peas) or roughage with high energy content (Emanuelson et al., 2006).

From an environmental point of view, importing meat and milk products may be justified when the production (including imports to Sweden) is performed more resource-efficiently and with less adverse environmental impact in other countries. However the supporting data for this report are not sufficient to identify actual examples. As regards the environmental objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*, living agriculture in Sweden is necessary to keep the landscape open and grazing animals need to be spread throughout the entire country in order to maintain pasture land. As consumers we can contribute by choosing meat from animals that have grazed on these pasture lands. By choosing local and regional products, the need for transport can be minimised.

6.7.3 Animal Consumption Impact on the Environmental Quality Objectives

The calculations based on nutritional recommendations show that nutritionally it is sufficient to eat about 100 g meat and 40 g cured or processed meat products daily. Current consumption statistics for meat and cured or processed meat products suggest that there is room for a reduction in the consumption of these without intake falling below the recommended levels. However, it is difficult to compare the statistics with the suggested consumption levels, since account needs to be taken of the uncertainties in the statistics and waste and losses during food preparation. By reducing meat consumption, several environmental benefits can be achieved, provided that there is a reduction in the consumption of products that contribute a small positive environmental impact or large negative environmental impact (Enghardt Barbieri & Lindvall, 2003; Jordbruksverket, 2007c).

If a large share of beef and lamb in Swedish meat consumption were replaced by pig and chicken meat, and Swedish beef and lamb meat consumption thus decreased sharply, there would be implications for several environmental quality objectives. This would impair the ability to preserve and maintain meadows and pasture, especially if the distribution of grazing animals became even more uneven than it is today. Moreover, conservation of meadow and pasture lands is an environmental objective in which agriculture has a highly important role. A large decline in grazing cattle and sheep may to some extent be compensated for by grazing horses, but these are probably concentrated to other geographical regions (mainly close to urban areas) than where most permanent pasture is located.

It is not possible to give any exact recommendation on how large a share of meat consumption should constitute meat from grazing animals and therefore how many grazing animals are needed in the country, since the number is dictated by the geographical distribution of the animals, the yield level of the pastures and the proportion of feed consisting of grazing. In some parts of the country ley is the dominant crop, e.g. in several counties in Norrland and the counties of Kronoberg

and Jönköping (Jordbruksverket & SCB, 2007b), due to the relatively favourable growing conditions and farm economics. In these regions it can be difficult both economically and practically to replace ley cultivation for feed for ruminants with other crop production and thereby also maintain an open agricultural landscape. However, a decreased proportion of cattle and sheep would reduce emissions of greenhouse gases and eutrophying substances (calculated per kg of meat on average).

The literature confirms that Swedish animal production performs well environmentally in international comparisons. Domestic animal production is also needed to achieve the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. If e.g. the proportion of beef should decrease in the diet, the reduction in the first place should occur through reduced imports, or through reduced use of Swedish animals that do not contribute to keeping the landscape open or graze natural pasture land. Currently there are no comprehensive studies of the environmental impact of e.g. Brazilian beef, but there is much evidence to suggest that the climate impact can be significant from this production.

The benefit of choosing local and regional animal products is that they contribute to supporting local farming and keeping the agricultural landscape open. This can be a particularly strong argument in regions with a small share of agricultural land (e.g. in forest districts) and where farming has greater difficulty in competing. Another benefit is that transport for e.g. the distribution of meat and milk can be minimised. Transport can also be limited through greater proportion of locally and regionally produced feed and more even distribution of animal and feed production.

To sum up, there is scope for reducing Swedish meat consumption without changing the dietary guidelines. Reduced meat consumption can, with appropriate prioritisation and allocation, provide several environmental benefits. From an environmental point of view and from an international perspective, Swedish meat production performs well, according to the literature. The first way to adjust meat consumption to reach the environmental quality objectives should be to reduce imports, which constitute about one-third of current meat consumption (LRF, 2005). Domestic production of beef and lamb is essential for preserving meadow and pasture land. Beef and lamb should primarily be produced using feed from natural grazing. There are also several benefits of choosing locally and regionally produced meat. Among other things, it reduces the need for transport of animals and feed and favours a more even balance between livestock and arable production within domestic agriculture. Sweden has large production of pork, but imports one-quarter of the amount consumed, as well as nearly half of the poultry meat consumed.

7. Edible Fats

The National Food Agency recommends that we use oils and soft dietary fats in cooking and low fat spreads on bread. Almost 35 per cent of the daily energy intake of Swedes derives from edible fats (Becker & Pearson, 2002). The National Food Agency recommendation is that 25-35 per cent of energy should come from fat (Nordiska Ministerrådet, 2004). Half the dietary fats consumed by Swedes consist of saturated fats, which is a too large a proportion (Becker & Pearson, 2002). At the same time, Swedes eat too little of the polyunsaturated fatty acids found in soft fats (for example cooking oil made from rapeseed or olives).

Consumption of edible fats decreased by about 30 per cent during the period between 1990 and 2005 (Table 7.1). The reason was that the consumption of butter and margarine decreased. The consumption of cooking oil and low fat spreads increased during the same period (Jordbruksverket, 2007c).

Table 7.1. Consumption of dietary fats between 1990 and 2005, kg per person (Jordbruksverket & SCB, 2007b)

	1990	2005	Consumption change 1990-2005
Butter	2.2	1.3	-40 %
Margarine excl. low fat spreads	11.6	5.6	-50 %
Low fat spreads	4.3	4.8	+10 %
Oils	0.8	1.7	+110 %
Total	18.9	13.4	-29 %

In Sweden, 120 000 tonnes oil from rapeseed, turnip rape, sunflower and soya bean for food consumption are used annually, of which the majority is rapeseed oil (Jordbruksverket, 2006b). The majority of oil goes to the manufacture of margarine and spreads.

Sweden's production and trade in oils and fats in 2006 is reported in Table 7.2. The most important trading partners for oils and fats were the Netherlands, Malaysia, Germany, Denmark, Norway and Italy. For butter and other butter fat products, the most important trading partners were Denmark, Germany, Great Britain and France (Jordbruksverket, 2007d).

Table 7.2 Sweden's production and trade of oils and fats, expressed in tonnes, in 2006 (Jordbruksverket, 2007d)

	Production	Import	Export
Rapeseed oil	100 000	43 000	14 000
Olive oil		6 000	350
Palm oil		130 000	25 000
Palm kernel oil		10 000	30
Soya bean oil		44 000	30 000
Coconut oil		8 000	1 300
Peanut oil		130	50
Sunflower oil		9 000	8 000

7.1 Palm Oil

Palm oil is a relatively new oil in the food industry. It is relatively cheap and it began to be used increasingly in cakes and other products when the negative consequences of trans fatty acids were discovered. Trans fatty acids are formed when an oil or a fat is not completely saturated, whereas when an oil or a fat is completely saturated no trans fatty acids are formed (Livsmedelsverket, 2008). The fatty acid composition of rapeseed oil is healthier than that of palm oil.

Per hectare, oil palm is the most productive oil crop in the world. It produces about four times more oil per hectare than rapeseed (Blix & Mattsson, 1998). It is estimated that in 2012, palm oil will be the world's most produced and consumed oil, as well as the most traded food oil (Dilworth et al, 2008). Palm oil is extracted from the pulp and palm kernel oil from the kernel. Palm oil is used in cooking and internationally it is one of the main ingredients in margarine and used in the food industry, because it is a cheap dietary fat and has food technology advantages. The oil is also used in detergent, soap and shampoo, as well as in cosmetics, animal feed (Dilworth et al., 2008) and steel production. Some palm oil is also used in the energy sector.

The oil palm originated in West Africa (Blix & Mattsson, 1998; Clay, 2004). It is cultivated today in Africa, South America and south-east Asia. The world's leading producers in 2005 were Malaysia (7.3 million hectares) (Dilworth et al., 2008) and Nigeria (3.4 million hectares) (FAO, 2007). Malaysia and Indonesia produce 85 per cent of the palm oil traded internationally (Clover, 2007). In 2007 Indonesia was expected to produce 16.8 million tonnes of palm oil and Malaysia 15.4 million tonnes (Ahmad, 2007). In Malaysia, the large oil palm expansion commenced in the 1960s. Many rubber plantations were replanted with oil palm and the Malaysian state initiated a programme that gave poor, landless farmers work and income by bringing plantations into cultivation in the jungle (Blix & Mattsson, 1998, Tengnäs & Svedén, 2002). During the 1990s, Malaysian oil palm enterprises began to invest in Indonesia, since the cost of land and labour increased in Malaysia (Clay, 2004). The Indonesian state was the largest oil palm producer in Indonesia in 1988, but by 1997 it owned only 20 per cent of Indonesia's 2.2 million hectares of oil palm. The remaining cultivations were owned by private enterprises (43 per cent) and small farms (37 per cent) (Clay, 2004).

According to Clay (2004), oil palm plantations comprise monocultures of between 400 and 70 000 hectares, while a study by Mattsson (1999) found that plantations were between 1 000 hectares and 6 000 hectares. The palm can be harvested for 40-50 years. New varieties are more productive, but for a shorter period (15-20 years) (Clay, 2004).

The major expansion of oil palm plantations which has in many cases taken place in tropical rainforest affects plants, animals and the indigenous people who live in the rain forest. The organisation RSPO has adopted a voluntary standard to ensure that palm oil is produced in a socially and environmentally acceptable manner (Colchester & Jiwan, 2006). The principles and criteria of the RSPO standard include among other things cultivation measures regarding erosion, biodiversity, plant protection products and soil fertility (WWF, 2007).

7.2 Rapeseed Oil and Other Oil Seeds

Significant acreages of oil crops other than oil palm and olives exist in India, China and Canada. The oil seeds produced are used mainly within the respective country. Canada and the EU account for the bulk of international trade (Fogelfors, 2001). The oil plants belong to the Brassica family, which includes rapeseed, turnip rape, Indian mustard (brown mustard), Ethiopian mustard and black mustard (Fogelfors, 2001). In Sweden, oilseed rape and turnip rape are the main oil seed brassicas cultivated.

In 2006, approximately 90 000 hectares of oil seeds were cultivated in Sweden (Jordbruksverket, 2006b). The acreage has increased in recent years after a sharp decline during the late 1990s to only 50 000 hectares. Winter and spring rapeseed are the main oil seed crops in Sweden, followed by winter and spring turnip rape and linseed. The total harvest of oil seed crops in Sweden was 220 400 tonnes in 2006, of which the majority was winter oilseed rape (151 000 tonnes) (Jordbruksverket, 2006b).

Oil seeds are a good break crop in cereal-dominated crop rotations and can in general reduce the need for plant protection products in the agricultural system. Rapeseed and turnip rape are vulnerable to several diseases and pests, mainly insects, and have poor competitiveness against weeds. This contributes to oil seeds still being cultivated organically only to a small extent (Fogelfors, 2001).

7.3 Olive Oil

World production of olive oil has increased from an average of 2.0 million tonnes in the 1990s to 2.5 million tonnes at the beginning of the 2000s. Olive oil accounts for slightly more than three per cent of the world's production of edible oils. Between 70 and 80 per cent of the world's production of olive oil comes from the EU. Global olive cultivation encompasses a total of 8.6 million hectares, of which 95 per cent is in the Mediterranean region. Olives are mainly produced in regions with relatively low productivity where no or few other crops can be grown. In

recent years the cultivation has partly changed, with an increasing share of intensive, densely planted cultivations, principally in Spain. A third of the olive acreage consists of intensive cultivation, which is responsible for 50 per cent of production. Traditional olive groves make up 50 per cent of the acreage and the remainder is comprised of marginal cultivations, which are responsible for one-tenth of olive oil production. The majority of olive tree plantations (holdings) are small, 1-5 hectares. (Jordbruksverket, 2004b)

7.4 Butter

Butter is made from cream, which is soured and churned. Butter contains 81-84 per cent butterfat. During production of butter in the dairy, buttermilk powder is also produced.

Of the milk delivered to dairies in 2006, six per cent was used for buttermilk powder and dietary fat products such as butter (Jordbruksverket, 2006c). For several decades since the end of the 1960s there was a surplus of butterfat, but the situation has now changed and the 'butter mountain' no longer exists (Jordbruksverket, 2007i). The reasons for this include increased demand for dairy products in Asia and reduced supply due to drought in Australia (Svensson & Johnsson, 2007).

7.5 Margarine and Spreads

Margarine and spreads consist of a mixture of solid and/or liquid vegetable fats and/or animal fats and water. A margarine should contain at most three per cent milk fat of the total fat content, while a spread should contain 10-80 per cent milk fat of the total fat content (EC, 1994). Several different oils and fats can be used as ingredients in margarine and spreads. The most common are rapeseed oil, sunflower oil, palm oil and, to a limited extent, coconut fat (Unilever, 2007).

7.6 Reduced Climate Impact

In the production of dietary fats the emissions of greenhouse gases from primary production are important. The climate impact and energy use in cultivation and manufacture of various cooking oils and butter are compiled in Table 7.3.

Literature searches failed to provide a basis for calculating the climate impact of butter production. Since values are lacking for butter, a rough estimate was made based on energy use and greenhouse gas emissions from milk production up to the farm gate (Cederberg & Flysjö, 2004a) and on data from Arla Foods for how much milk is required to produce butter (Table 7.3). In general, the largest environmental impact for milk arises from primary production, i.e. from agriculture (Cederberg & Flysjö, 2004a). This is assumed to apply also to butter production.

Table 7.3. Energy use and potential climate impact associated with production of dietary fats. Energy use is expressed as secondary energy, that is in the form it is used in processes (for example diesel for tractors)

Product	Energy use (MJ/kg)	Potential climate impact (g CO₂-eq/kg)	Production information	Reference	Comments
Palm oil	Diesel 2.9, Electricity 1.7, Steam 8 (electricity -0.6)	0.3 ¹	19 ton/ha/year, which gives 4 000 kg palm oil	Yusoff & Hansen (2008)	1 kg palm oil ready for delivery from Malaysia. Cultivation, transport and oil production. Based on general data from a number of studies, thus quality is limited.
Olive oil (virgin oil)	13 ²	1.2 ¹	5 000 kg/ha/year which gives 1 000 kg oil ³	Notarnicola et al. (2004)	1 kg extra virgin olive oil ready for delivery. Cultivation, transport and oil production.
Olive oil, organic (virgin oil)	Oil 15	1 ¹	5 000 kg/ha/year which gives 1 000 kg oil ³	Notarnicola et al. (2004)	1 kg extra virgin olive oil ready for delivery. Cultivation, transport and oil production.
Rapeseed oil	4.9 (primary energy: fossil fuel 6, biomass 2, electricity 2)	0.8	3 200 kg/ha/year winter rapeseed, 2 100 kg/ha/year spring rape seed. Yield ratio: 40% oil and 6% rapeseed meal	Cederberg & Flysjö (2007)	1 kg Swedish rapeseed oil ready for delivery from the producer. A positive crop rotation effect was attributed to the rapeseed. Environmental impact and resource use allocated between the main product oil and the by-product rapeseed meal by system expansion. Avoided soya import attributed to the rapeseed.
Rapeseed oil	6.9 (primary energy: fossil fuel 7.6, biomass 2.5, electricity 2)	1.0	3 200 kg/ha/year winter rapeseed, 2 100 kg/ha/year spring rapeseed. Yield ratio: 40 % oil and 6 % rapeseed meal	Cederberg & Flysjö (2007)	1 kg Swedish rapeseed oil ready for delivery from the producer. A positive crop rotation effect was attributed to the rapeseed. Environmental impact and resource use allocated between the main product oil and the by-product rapeseed meal by economic allocation (72% oil and 28% rapeseed meal).

Butter	14-15 fossil fuel 5 electricity	6-7	34 kg whole milk (4 % fat) gives 1 kg butter, 32 kg semi-skimmed milk (1,5 % fat), 1 kg buttermilk		Rough estimate for 1 kg butter. Data for milk production from Cederberg & Flysjö (2004a), including primary production to farm gate. Data for dairy production from Arla Foods (Larsson, 2007). Economic allocation: 21% butter, 78% semi-skimmed milk and 1% butterfat according to sales prices of Arla Foods)
Butter, organic	9 fossil fuel 5 electricity	7			

¹ General estimate of greenhouse gases based on fertiliser production assumed to generate 6.8 kg carbon dioxide equivalents per kg of fertiliser (Jensen & Kongshaug, 2003). Diesel use assumed to generate 74 g carbon dioxide equivalents per MJ at combustion (Uppenberg et al., 2001). Does not include electricity production.

² Overall estimate of energy use based on fertiliser production requiring 40 MJ/kg of nitrogen (Jensen & Kongshaug, 2003). Diesel use and mineral fertilisers (90 kg N/ha) according to Notarnicola et al. (2004).

³ 5 kg olives produce 1 kg of olive oil (Notarnicola et al., 2004)

The greenhouse gas emissions from palm oil production shown in Table 7.3 do not include potential carbon dioxide emissions caused by land use change due to increased oil palm cultivation. These emissions are particularly relevant for recently established palm oil plantations where there was previously rainforest. According to a Malaysian study (Yusoff & Hansen, 2008), the biomass in the rainforest contains around 250 tonnes of carbon per hectare, while a mature oil palm plantation contains about 100 tonnes of carbon per hectare. If the difference of 150 tonnes of carbon is assumed to be released as carbon dioxide, this is equivalent to around 550 tonnes of carbon dioxide.

Yusoff & Hansen (2008) point out the significance of this and compare it to one hectare of oil palm plantation, which during its lifetime gives rise to emissions of about 2 000 tonnes of carbon dioxide from cultivation and oil production.

In the production of palm oil (including cultivation and production of oil), half the climate impact is reported to derive from the production of commercial fertilisers and the remaining half from fuel use in cultivation (Yusoff & Hansen, 2008; Table 7.3). According to those authors, the steam which is used in oil production is generated from crop residues, i.e. a renewable energy which does not generate any net carbon dioxide emissions. Furthermore, the production of oil generates more electricity than is consumed in the process (Yusoff & Hansen, 2008). The study does not indicate how common it is for palm oil production to generate electricity. Another source of greenhouse gases which is not included in the study is the biogas generated from by-products arising during oil production, but knowledge about how it is handled was considered to be lacking (Yusoff & Hansen, 2008).

In the production of conventional olive oil, around 60 per cent of the climate impact arises from the production of fertilisers and the remainder from fuel use during cultivation (Notaricola et al., 2003). For organic olive oil the climate impact derives entirely from fuel use and thus organic olive oil gives rise to lower emissions of greenhouse gases than conventional. However, fossil fuel use is greater in production of organic olive oil than conventional, since it is greater both in cultivation and in the transport of olives than for conventionally cultivated olives (Notaricola et al., 2004). Extra virgin olive oil probably requires less energy in production than olive oil. This is because the first oil (extra virgin) is only cold-pressed, while oils of other quality are extracted from the press residues using several inputs such as extraction agents and heat and several of the associated cleaning stages are very energy-demanding (Jordbruksverket, 2004b; Notaricola, 2007). There is a lack of knowledge about the climate impact of different qualities of oil, expressed per kg oil.

The estimate of climate impact for butter (Table 7.3) includes greenhouse gases from milk production, i.e. primarily methane from animal digestion of feedstuffs and storage of manure, and nitrous oxide from fertilisation with nitrogen fertilisers. During milk production the fossil energy use is lower for organic butter than for conventionally produced butter (Cederberg & Flysjö, 2004a). However, the emissions of greenhouse gases from cows in organic and conventional production are of the same order of magnitude, because conventional production includes high milk yields and consequently lower methane emissions per kg milk

than organic production. Butter generates a relatively high climate impact. Another mode of allocation than economic allocation, for example in accordance with energy content, would assign a different climate impact to butter but it would probably still be higher than for the vegetable oils (Table 7.3).

7.6.1 Margarine

A life cycle assessment study (from cultivation to waste management) of margarine (80 per cent fat) and low-fat margarine (38 per cent fat) showed that the higher fat margarine has its greatest climate impact during primary production (cultivation) (Shonfield & Dumelin, 2005). For low-fat margarine the other parts of the life cycle (processing, refrigerated distribution, packing and consumer phase) accounted for more than half the energy use and climate impact. The study showed that dietary fats with lower fat content had slightly lower climate impact (about 10 per cent) than those with high fat content. These differences were explained by the fact that in low-fat margarine the fat was largely replaced by water, which has little environmental impact.

Shonfield & Dumelin (2005) also compared the life cycles (including cultivation, oil production and transport) of the dietary oils included in the above margarine types. The results showed that palm oil (Malaysia) and coconut oil (Malaysia) required approximately 60 per cent less energy than sunflower (South Africa) and olive oil (Spain). Rapeseed oil and soya bean oil required about 20 per cent less energy than sunflower and olive oil.

Climate impact was least for palm oil and greatest for sunflower oil (Shonfield & Dumelin, 2005), with coconut oil, soya bean oil, rapeseed oil and olive oil placed between these, in increasing order of impact. The study noted that cooking oils with the lowest climate impact had the highest content of saturated fats. Greenhouse gas emissions from land use change are not mentioned in this study.

7.7 A Non-Toxic Environment

7.7.1 Palm Oil

Blix & Mattsson (1998) indicated that oil palms in Malaysia older than one and a half years are sprayed twice a year with herbicides. Current information about plant protection in olive palm plantations is lacking. Chemical plant protection products are permitted according to the RSPO criteria (RSPO, 2007). For example, it is permitted to use paraquat in RSPO-certified production, but this has resulted in criticism from among others the Pesticide Action Network, PAN (PAN Netto, 2007).

Insect infestation is a problem in oil palm plantations. In Malaysia, the substance monocrotophos is injected into the stem of the infested palms, where it spreads systemically in the palm and kills the insects that attack the foliage. Monocrotophos is an organophosphate which is toxic to humans and ecotoxic. The substance only exists in the water phase in the palm and there is consequently

no trace of it in the oil phase (Blix & Mattsson, 1998). Monocrotophos is classified as ‘highly hazardous’ on the WHO list of pesticides toxic to humans (IPCS, 2005).

7.7.2 Rapeseed oil

Oilseed rape and turnip rape are vulnerable to several pests and diseases. The most important pests of rapeseed are pollen beetle and brassica pod midge. Snails can also be a problem. To control these pests, pyrethroid compounds are used (Blix & Mattsson, 1998). Pyrethroids are classified as ‘moderately hazardous’ on the WHO list of pesticides toxic to humans (IPCS, 2005).

In a European perspective, Sweden is characterised by low use of plant protection products in oil plant cultivation. Figure 7.1 shows the average quantities of active substance used per hectare of oil plants for some EU countries in 2000-2003 (Europeiska kommissionen, 2007). Sweden together with other Scandinavian countries and Belgium use relatively small amounts of plant protection products in oil plant production. Oil plants are a good break crop in cereal-dominated crop rotations, which generally reduce the need for plant protection products in the cultivation system.

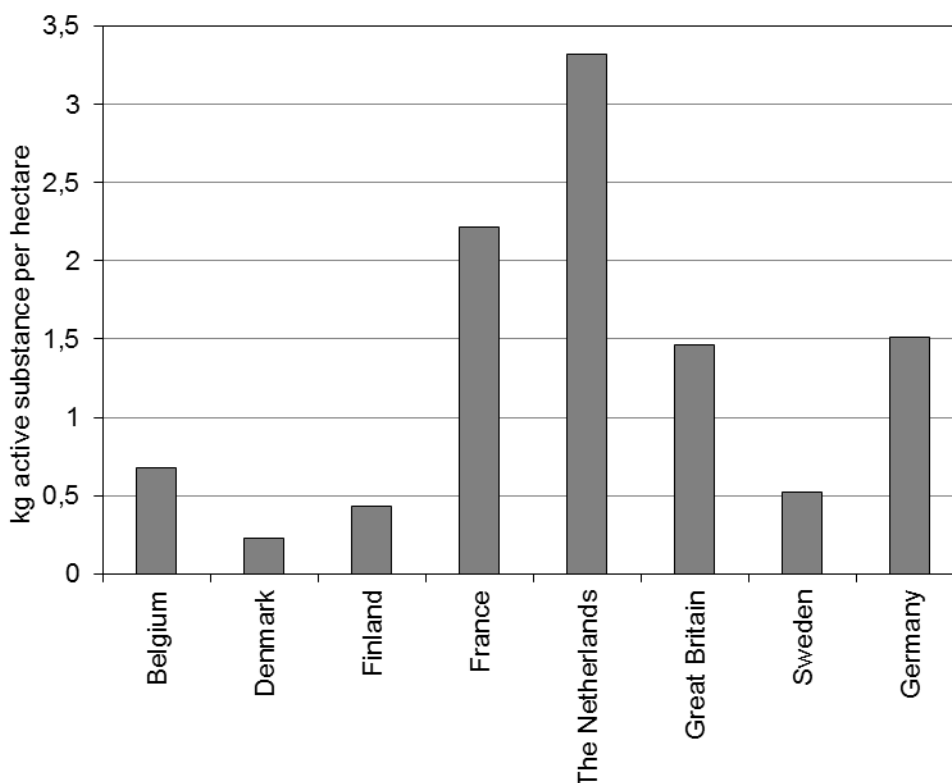


Figure 7.1 Use of plant protection products in oil plant production (Europeiska kommissionen, 2007).

7.7.3 Olive Oil

The olive fruit fly is the primary pest of olive trees (EFNCP, 2000; Jordbruksverket, 2004b). The larvae of the fly damage the olives. The problems are greatest in humid and frostless climates. In the cultivation of olives for oil production, infestations with olive fruit fly give rise to losses of unripe fruit and, in addition, the tunnels that the larvae make in the olives reduce the quality of the olive oil. Chemical control of pests, mainly the olive fruit fly, is conducted by each grower spraying individual trees or by large-scale spraying using aeroplanes (EFNCP, 2000; Dessane, 2003). The Swedish Board of Agriculture (Jordbruksverket, 2004b) has concluded that the problems with olive fruit fly are serious because the olive trees are grown as perennial monocultures.

The substance dimethoate is an insecticide used in olive cultivation (EFNCP, 2000; Dessane, 2003; Notarnicola et al., 2004; Kaltsas, 2007). Dimethoate is classified as 'moderately hazardous' on the WHO list of pesticides toxic to humans (IPCS, 2005). Dimethoate is a broad-spectrum chemical plant protection product which eliminates several different insect species (EFNCP, 2000). However, it can also lead to beneficial insects that parasitise pests being harmed.

Methidathion is used against black scale (*Saissetia oleae*) (EFNCP, 2000; Dessane, 2003; Notarnicola et al., 2004). Methidathion is classified as 'highly hazardous' (IPCS, 2005).

Herbicides are also used in olive cultivation, in order to keep the area under the trees free of weeds (Jordbruksverket, 2004b).

In traditional conventional cultivation, the use of plant protection products is often less prevalent than in intensive cultivation. In organic olive cultivation preventive measures such as pruning, adjusted fertilisation, etc. are used in order to reduce problems with diseases and pests (EFNCP, 2000).

7.7.4 Butter

The plant protection products used in the production of conventional dairy fat/butter are those used in the cultivation of feed for dairy cows. According to Cederberg & Flysjö (2004a), a large proportion of the plant protection products used in Swedish conventional milk production can be linked to imports of feed, including soya. Soya is imported mainly from Brazil. According to an older life cycle assessment of milk production the plant protection products monocrotophos, endosulfan and 2.4-D are used in soya bean cultivation (Cederberg, 1998). Endosulfan and 2.4-D are classified as 'moderately hazardous' on WHO list of pesticides toxic to humans (IPCS, 2005).

In organic milk production no chemical plant protection products are used. In the past, five per cent of purchased feed for organic cows was allowed to be conventionally cultivated, but since 2008 100 per cent of the feed used for organic ruminants must be organic (EG, 1991; KRAV, 2007).

7.8 A Varied Agricultural Landscape and A Rich Diversity of Plant and Animal Life

7.8.1 Palm Oil

The most serious problem with palm oil production is when rainforest with high natural values, so-called High Conservation Value Forest (HCVF), is replaced with oil palm plantations. This means that the habitat for plants and animals disappears and the number of endangered species increases. The greatest problems with this are in Indonesia (Clay, 2004).

The conversion of tropical rainforest into oil palm plantations is resulting in a decrease in the number of species of animals and plants. Studies have shown that the number of species can decrease from 75 to 10 species (mammals) per hectare (Mattsson et al., 2000). There are also many endemic species in the Malaysian rainforest and it is of particular importance that these are protected. Among the mammals which are under severe threat in Malaysia are the Asian elephant, the Sumatran rhinoceros, the orangutan and the tiger (Clay, 2004).

The olive palm plantations in Malaysia are in many cases large and continuous, with few remaining islets of other vegetation (Blix & Mattsson, 1998). This means that there is often a lack of green corridors for wild animals and plants to move along between the reserves of rainforest that still exist (Clay, 2004). Olive palm cultivation in Indonesia is expanding sharply, by 6-7 per cent per annum according to Emanuelsson et al. (2006).

In oil palm plantations soil erosion is a problem. In Malaysia, erosion can amount to between 7.7 and 14 tonnes per hectare and year, where the higher figure is mainly on tracks and passages where infiltration capacity is low (Blix & Mattsson, 1998; Mattsson et al., 2000). When rainforest is cleared for olive palm plantations, there is a risk of the organic matter content being reduced during the establishment phase. In more mature plantations the literature suggests that organic matter content can be somewhat lower than in a rainforest (Blix & Mattsson, 1998).

7.8.2 Rapeseed Oil

There are no studies that assess how the cultivation of rapeseed affects biodiversity. In general, oil seed crops can result in higher diversity and an improved crop rotation, because they act as an alternate crop in very cereal-dominated crop rotations.

Rapeseed cultivation must be considered as part of the cultivation system and a general assessment of the Swedish cultivation landscape must be viewed in a historical perspective. The structural change that began in Swedish agriculture in the 1960s meant that marginal land was not profitable for farming, which led to large-scale production in the plains districts. This large-scale production led to

many of the historical elements of the cultivated landscape, for example tree-lined avenues, open ditches, farm tracks and splitrail fences, being removed or abandoned. As a result, many of the plant and animal species that belong in the agricultural landscape are today on the list of endangered species (Jordbruksverket, 2003a).

Oliferous plants have a generally positive effect on pollinating insects such as bees and bumble-bees, provided that they are not sprayed with insecticides during flowering (Cederberg B, 2007). However, the impact of oliferous plants on bees and bumble-bees is unclear, since the structural change within agriculture has reduced the amount of natural vegetation (meadowland and pasture land where there are resource plants for bees and bumble-bees) in the agricultural landscape. This in turn has adversely affected the population of wild bees (Pettersson et al., 2004; Cederberg B, 2007).

Since rapeseed is included as one of the crops in crop rotations, rapeseed cultivation must be seen as a part of the cultivation system. Similar effects on the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diverse Plant and Animal Life* can consequently be expected for organic oil crops as for organic cereal and potato cultivation (Section 4.5.1).

In Sweden erosion of arable soil is a minor problem. Blix & Mattsson (1998) calculated that the erosion in rapeseed cultivation in Skåne was 0.03-0.05 tonnes per hectare and year. In northern Europe the annual loss of topsoil through erosion amounts in general to an estimated 0-1 ton per hectare and year (Kirkby et al., 2004).

There are no unequivocal data on how different types of farming affect soil properties. The separation of animal husbandry and cereal cultivation which has taken place in Swedish agriculture has resulted in reduced organic matter content in some arable soils. In general, however, the organic matter content in Swedish soils is good. Across the country the proportion of soils containing less than three per cent organic matter (low humus soils) is less than five per cent (SCB et al., 2007). Organic matter content can be built up by cultivating perennial leys, adding a lot of organic material to the land (e.g. crop residues, organic fertilisers such as farmyard manure and compost) and reducing tillage.

7.8.3 Olive Oil

There is little literature data on biodiversity in olive cultivation. An evaluation of olive oil production in the EU from an environmental perspective indicates that there are few studies on how different olive cultivation systems affect biodiversity (EFNCP, 2000).

Beaufoy (2000) states that biodiversity is higher in traditionally managed olive cultivation compared with intensive cultivation due to the structural diversity (species of trees, other vegetation, areas with natural flora and fauna, stone walls, etc.) being greater than in more intensive cultivation. This structural diversity results in a diversity of habitats for flora and fauna.

In olive cultivation the substance dimethoate, which is a broad-spectrum substance included in many insecticides, is often used (EFNCP, 2000). It can cause harm to beneficial insects that parasitise pests and other insects, which leads to an adverse impact on *A Rich Diversity of Plant and Animal Life*.

Olive plantations are monocultures. In Greece, the plantations are often small, relatively old-fashioned and located in marginal terrain. In Spain, however, the cultivations are often larger and more intensive (Jordbruksverket, 2004b).

Olive cultivation has been an element in the landscape around the Mediterranean for nearly 3 000 years (Jordbruksverket, 2004b). Traditional olive cultivation is therefore characteristic of the landscape according to EFNCP (2000). This does not apply generally, since the landscape picture is more uniform in southern Spain (Andalusia) where olive cultivation dominates the landscape in vast areas through monocultures and where olive trees are the only vegetation visible during large parts of the year (EFNCP, 2000).

Soil erosion is one of the greatest environmental problems with olive cultivation in the Mediterranean region (EFNCP, 2000; Dessane, 2003; Jordbruksverket, 2004b). According to a general assessment of the erosion risk in Europe, there are areas in southern Europe (Spain, Italy and the south of France) where the annual loss of topsoil through erosion is 5-10 tonnes per hectare and year (Kirkby et al., 2004).

The erosion problem is greatest in intensive cultivation, where the soil under the olive trees is often ploughed or harrowed in order to prevent weeds from competing with the trees. In Andalusia in southern Spain, there are indications that erosion may be more than 80 tonnes per hectare and year in the most vulnerable plantations along slopes. In less hilly regions too, erosion in olive groves may be considerable, around 40 tonnes per hectare and year (EFNCP, 2000).

In order to counteract the problem of erosion, olive trees should be grown in rows that follow the contours of the landscape. Another important factor is to cultivate a cover crop on the soil under the olive trees.

7.8.4 Butter

Much of the biodiversity in the landscape can today be linked to pasture and meadow. Grazing animals are important in order to preserve the values of pasture land (Jordbruksverket, 2003a). However, increased butter consumption does not mean automatic support for natural grassland, since many animals today graze on more energy-rich cultivated leys or are reared on feed other than pasture (Jordbruksverket, 2007h). Economic conditions and changes in farm structure have also resulted in the acreage of pasture land declining sharply. The natural pastures that still remain are also less continuous, which can make preserving the land's biodiversity more difficult (Jordbruksverket, 2003a).

There is scientific support for the theory that people in Sweden value variation and activity in the landscape (Drake, 1991). According to Emanuelsson et al. (2006), grazing animals can be seen as an element that contributes to an open and varied agricultural landscape.

Sweden currently has less than 7-8 per cent agricultural land, which together with Finland is the least in the EU (Jordbruksverket, 2003b). In comparison, Denmark has 63 per cent agricultural land. While certain regions, primarily in the south, have larger proportions of agricultural land, overall such land is scarce in Sweden. This means that it is important to retain the agricultural land that exists in Sweden in order to maintain variation in the landscape, which is the foundation of biodiversity.

Imports of feedstuffs for dairy cows can lead to adverse effects on biodiversity in other countries. Concentrates such as soya or palm kernel expeller can give rise to clearing of rainforest or other land, which results in loss of biodiversity (Emanuelsson et al., 2006).

In a study from the late 1990s on the condition of Swedish arable land, the organic matter content of the soil tended to be higher on farms with cattle than on farms without animals or on pig farms (Eriksson et al., 1997). The difference between these is that farms with cattle cultivate a lot of leys, which can build up soil organic matter. Ley cultivation is also a way to reduce the risk of soil compaction, since it enhances the soil structure.

As regards imported feedstuffs for dairy cows, their production in other countries can generate problems with soil compaction and erosion (Emanuelsson, 2006).

7.9 Discussion and Conclusions

Production of palm oil requires less fossil energy than other oils. This means that the emissions of greenhouse gases from the cultivation and production of palm oil are lower than for other oils. In the case of palm oil, however, the system's total carbon storage should be included in the system boundaries if the palm oil comes from newly established oil palm plantations where the land was previously rainforest. A Malaysian study that compared the carbon content in the biomass in a mature olive palm plantation with that of a rainforest found the difference to be 150 tonnes carbon dioxide, which would give rise to 550 tonnes carbon dioxide assuming that all of this carbon is released as carbon dioxide. A more fair comparison would be the average carbon storage during the life of the plantation, which would still result in a greater climate impact. Clearly land use change through deforestation accounts for significant emissions of greenhouse gases. This may indicate that palm oil gives rise to more greenhouse gases than other dietary fats due to land use change. The production of palm oil on former wetlands generates carbon dioxide emissions which place Indonesia as number three among the world's top carbon dioxide emitting nations (Silvius, 2006).

The literature and simplified calculations suggest that the production of butter (primary production) generates more greenhouse gases than the production of

edible oils such as rapeseed and olive oil (during primary production and oil production). Comparing butter and palm oil is more difficult because the land use that oil palm plantations may cause makes the amount of greenhouse emissions from palm oil unclear. From a climate change perspective, no differences have been found between butter from organic and conventional milk.

The fossil energy use in the production of Swedish rapeseed oil may be lower than that in the production of Italian olive oil. The climate impact from these oils can be assumed to be of the same order of magnitude, but when Swedish rapeseed oil is produced in a large efficient processing plant where some of the energy use is based on biofuels, the climate impact can be less than for olive oil. For olive oil transport to Sweden adds to its climate impact, which means that the position of Swedish rapeseed oil can be improved further compared with olive oil.

For table spreads, the literature suggests that low-fat alternatives have slightly lower climate impact per kg than margarine with 80 per cent fat content. Since the consumption of low-fat spreads has increased in recent years, this may mean that the emissions of greenhouse gases from the Swedish consumption have been reduced. On the other hand, regarding climate impact palm oil in margarine and spreads gives large uncertainties due to land use change in oil palm cultivation (see above).

Chemical plant protection products classified by WHO as highly hazardous to humans are used in conventional oil palm plantations and olive groves. The plant protection products currently used in the production of conventional dairy fat/butter are those used during the cultivation of feed for dairy cows. In conventional soya from South America, which is fed to dairy cows, plant protection products that are very harmful to humans are used. In general, smaller amounts of plant protection products are used in Sweden and in neighbouring Nordic countries. If the environmental quality objective *A Non-Toxic Environment* is seen from an international perspective, this may mean that rapeseed oil produced from Swedish rapeseed can be considered to cause less risk of adverse impact than other fats.

Based on the environmental quality objective *A Non-Toxic Environment*, organic products are preferable since they involve very little or no use of plant protection products and therefore little risk of adverse impacts caused by chemical plant protection products.

According to the environmental quality objective *A Rich Diversity of Plant and Animal Life*, biodiversity must 'be preserved and used sustainably'. Since oil palm plantations in Malaysia and Indonesia represent a relatively new cultivation system and entail forests with high conservation values being cut down, the number of species decreasing, endemic species being threatened and the number of endangered animals increasing, the adverse effect of palm oil on biodiversity is considered to be greater than for other dietary oils.

The demand for vegetable oils is increasing in the world. Since palm oil is relatively cheap, this results in new oil palm plantations being developed. The voluntary certification system which has been developed recently is a step towards olive palm cultivation with greater environmental consideration.

Information on biodiversity levels in olive and rapeseed cultivations is limited. The trend within olive cultivation is for increased intensification, especially in Spain. This leads to increasingly larger monocultures, where biodiversity is likely to be adversely affected. The use of chemical protection products adds to this. In Sweden, a similar intensification has taken place during the structural change in agriculture. In general, this has led to a lack of small-scale biotopes and culturally significant landscape elements. Within Swedish agriculture, however, there is not the same type of widespread monoculture as in intensive olive cultivation. Rapeseed cultivation can instead be considered a positive element in Swedish crop rotations and in the landscape. Moreover, erosion can be very large in olive groves, which is not a problem in Swedish rapeseed cultivation. Rapeseed cultivation can instead generate a positive aesthetic value at the landscape level according to Drake (1991). In an international perspective, this means that rapeseed oil can contribute positively to the environmental quality objective *A Varied Agricultural Landscape* and less negatively to *A Rich Diversity of Plant and Animal Life* compared with olive oil from intensive cultivation.

It is difficult to assess the impact of butter production on the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*. Grazing animals could be an important advantage of butter, since much of the biodiversity in the agricultural landscape can be related to pastures and meadows. However, production changes and economic conditions have led to the acreage of pasture land decreasing sharply. Nevertheless, grazing animals are considered to be positive in a landscape perspective and dairy cows contribute to diversity in the landscape, which is an important foundation for biodiversity. Imported feed (e.g. soya) may instead lead to negative consequences in other countries, such as erosion and loss of biodiversity.

Organic butter can be advantageous, among other things because no conventional feed is permitted and cultivation of green manure crops has a positive effect on the organic matter content of the soil.

The National Food Agency's dietary guidelines includes eating a larger proportion of soft fats and the tendency today is that the consumption of edible oil is increasing. In particular, rapeseed oil and olive oil have a more favourable fatty acid composition than butter and palm oil. Rapeseed oil is considered to have the least adverse environmental impact and the greatest positive impact on all four environmental quality objectives studied. Olive oil is considered to have the next least negative environmental impact.

The use of palm oil has increased significantly in the food industry. From an environmental perspective this may entail greater environmental impact based on the environmental objectives discussed in this study. Increased use of palm oil may adversely contribute to the environmental quality objective *Reduced Climate Impact*, mainly through the deforestation that oil palm plantations can lead to

emissions of greenhouse gases. The plantations can adversely contribute to the environmental quality objective *A Rich Diversity of Plant and Animal Life* through valuable habitats of many plants and animals disappearing. The large-scale cultivation in perennial monocultures also has an adverse effect on the environmental quality objective *A Varied Agricultural Landscape*.

From an environmental perspective, a continued reduction in butter consumption could contribute to fewer grazing animals in the landscape and reduced grazing areas, which can have an impact on *A Rich Diversity of Plant and Animal Life* and *A Varied Agricultural Landscape*. On the other hand, decreased butter consumption may lead to reduced climate impact from primary production (milk production), thus contributing to the environmental quality objective *Reduced Climate Impact*. However, it is important to remember that the open landscape requires grazing animals where integrated meat and milk production is more environmentally efficient than specialist systems for meat and milk production. From an environmental point of view it is important to use as much of the products from dairy cows as possible. Consequently, balanced consumption of dairy products is important, that is a product mix in which butter can also be included, which ensures a more efficient use of the animal.

In conclusion, it would be environmentally beneficial to reduce the use of palm oil to the advantage primarily of rapeseed oil and secondly olive oil. It is generally desirable to choose organic oils and dietary fats. As regards butter, it is desirable from an environmental point of view that both low-fat and high-fat products are used, so that the entire production of the cow can be utilised.

8. Bottled Water

8.1 Consumption of Bottled Water

Swedish consumption of bottled water in 2006 amounted to 27 litres per person (Sveriges Bryggerier, 2008a), which is equivalent to a total of 247 million litres (Sveriges Bryggerier, 2008b). Bottled water consumption has thus more than doubled in ten years. The consumption of soft drinks in 2006 was 74.6 litres per person (Sveriges Bryggerier, 2008c), which is equivalent to an increase of 18 per cent during the same period.

Sales of flavoured water have increased, as have sales of non-carbonated bottled water (still mineral water). Still water requires higher hygiene standards at bottling than carbonated water or the addition of preservatives (KSLA, 2004).

8.2 The Environmental Impact of Bottled Water

Management of bottled water includes resource use and energy use over the entire life cycle, from the manufacture of fuels and materials (for example for packaging and packaging materials) via water production, treatment and packing, distribution, to storage and consumption. Waste management and transport are included in connection with all these steps.

Angervall et al. (2004) investigated the environmental impact of different types of bottled waters, including origin, various brands and packaging options, using data on production, cleaning, filling, recycling and waste management taken from a comprehensive study of drinks packaging for Swedish conditions (Ekvall et al., 1998; Person & Ekvall, 1998). The transport of bottled water was adjusted in accordance with Swedish consumption. The study by Angervall et al. (2004) also compared the results for various bottled waters with Stockholm tap water. The least environmental impact of all was for tap water, while the different kinds of bottled water generated between 40 and 180 g carbon dioxide equivalents per litre of water.

The production of bottled water (incl. production of the bottles, reuse/recycling and waste management) accounted for the largest share of greenhouse gas emissions per litre of water from all types of water (Angervall et al., 2004). The authors indicate that the European electricity mix gave rise to apparent increased emissions compared with the cases when Swedish electricity was used. Returnable bottles, which are refilled after cleaning, gave less environmental impact than PET bottles where the material is recycled into fleece fabric, new PET bottles, etc. Water in 330 ml returnable glass bottles (recycling) gave a greater climate impact than 1.5 litre returnable PET bottles (recycling). Smaller packs contain more material per unit volume, so the environmental impact per litre of water from packaging increases with decreasing pack size. Ekvall et al. (1998) showed that

500 ml disposable PET bottles give rise to 2-4 times the climate impact and 500 ml aluminium cans 2-3 times the climate impact of 500 ml PET bottles which are refilled.

Transport represents a significant part of the climate impact for bottled water (Angervall et al., 2004). Shorter distance is important, together with the mode of transport. The study showed that shorter distances and transport by rail generated significantly less climate impact. Imported water types gave rise to the greatest climate impact. The authors also established that home transport of bottled water can comprise a very large proportion of the climate impact. For water in 1.5 litre returnable bottles transported within the country and mainly distributed by rail, transport to the home can give rise to a greater climate impact than production and freight (Angervall et al., 2004).

Rough estimates of carbon dioxide emissions from transport of different foreign bottled waters than in the above study confirm the significance of transport in the environmental profile of bottled water (Kerpner, 2007).

Godwin et al. (2007) point out that the material in the plastic bottles for bottled water derives from fossil oil and that bottled water accounts for a significantly larger water use than tap water.

8.2.1 Environmental Impact at the Retail Level

Although not necessary for shelf life, an increasing proportion of small bottles are stored and displayed in chiller cabinets. In addition to supermarkets, chilled beverages are available for example in cinemas, kiosks and petrol stations. At these outlets, water is displayed in chiller cabinets and refrigerated stands, which occupy space and generate a need for refrigeration equipment involving for example production, operation and waste management (of refrigeration equipment). This increased resource and energy use generates an increased environmental impact.

8.3 Discussion and conclusions

The environmental impact of increased or reduced consumption of bottled water depends on the reference point chosen, for example whether bottled water it is assumed to replace tap water or a more complex beverage such as a soft drink or beer. From a health point of view, we need water. We do not need sugary drinks or water flavoured with aromatic substances. It is therefore reasonable to regard our consumption of bottled water as a type of beverage that does not fill any nutritional need. From this perspective, consumption of bottled water can be regarded as a luxury consumption similar to that of soft drinks, wine, beer or other alcoholic beverages.

Since total consumption of soft drinks and bottled water in Sweden has increased significantly during the past decade, we can conclude that the quantity of bottled drinks has increased markedly. Soft drinks and bottled water are consumed in

similar packaging (in terms of size and materials), which means that it is reasonable to assume that the environmental impact from packaging and distribution are similar expressed per quantity of beverage, provided that the origin is similar. The environmental impact of the contents thus remains. We can establish that soft drinks contain more ingredients than bottled water, thus adding the environmental impact from additional raw materials which are processed, handled and distributed compared with bottled water. Thus if bottled water is regarded as a replacement for tap water, it contributes to increased environmental impact, while if it is regarded as a replacement for soft drinks, it contributes to reduced environmental impact.

The overall increase in consumption of bottled beverages has contributed to increased environmental impact from the different stages in the life cycle, from production to consumption and waste management. Consequently, reduced consumption of bottled beverages would in itself contribute to reduced environmental impact. This implies that we should replace some bottled drinks with similar non-bottled beverages, in other words tap water. If flavour is desired then this can be provided by for example adding a slice of apple, which can be consumed with the water. In the first instance, more environmentally sound consumption of bottled beverages would involve reduced consumption.

Choosing bottled water packaged in returnable bottles that are reused and packaging with little material per bottle contributes to reducing the environmental impact from bottled water consumption. Using less material per litre of water to reduce the environmental impact can be achieved by choosing larger packs. However, this presupposes that the consumer drinks the entire contents of the bottle without increasing total consumption. Since transport constitutes a significant part of the climate impact of bottled water, choice of short-transport water also contributes to reducing the climate impact. If the transport also takes place by rail instead of road, the climate impact is further reduced. Consuming beverages at room temperature rather than chilled would also probably contribute to reducing the environmental impact from the infrastructure required for chilled beverages.

When regarded as water, water in bottles adversely contributes to the environmental quality objective *Reduced Climate Impact*, where packaging and transport comprise a substantial component. The environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life* are mainly indirectly affected by the impact derived from the manufacture of plastics and machines/vehicles (the infrastructure required to manufacture and transport bottled water), waste in landfills and incineration of waste, as well as from transport (roads, particulate matter and deposition). The manufacture of plastics results in emissions of metals and fumes. Internationally, landfilling and the dumping of waste in the countryside is more common than in Sweden, where the degree of recycling is high.

The GRK Strategy which covers non-toxic, resource-efficient cyclical systems is probably positively affected by minimisation of unnecessary transportation and resource flows. Since bottled water can be regarded as a luxury product, where

there is no nutritional justification for filling the water into a bottle rather than using tap water, decreased use of bottled water can contribute positively to the GRK Strategy.

Seen in the perspective of entire national consumption, the environmental impact from bottled water only comprises a small share, but the figures are not negligible. Arla Foods has calculated that in 2003, Swedish bottled water consumption of 181 million litres gave rise to emissions amounting to around 74 000 tonnes of carbon dioxide equivalents, equivalent to the emissions from the combustion of 28 400 cubic metres of oil (KSLA, 2004). The Stockholm Consumer Cooperative Society calculated that the environmental load from bottled water amounted to 30 000 to 38 000 tonnes of carbon dioxide equivalents (Konsumentföreningen Stockholm, 2007).

The consumption of bottled water and soft drinks in the world and in Sweden is increasing, which is contributing to increased environmental impact. The manufacture of bottles for bottled water in the USA in 2006 was calculated to require 2.7 million cubic metres of oil and to give rise to more than 2.5 million tonnes of carbon dioxide emissions (Pacific Institute, 2008). World consumption of bottled water requires 2.7 million tonnes of plastics (Arnold & Larsen, 2006).

9. Conclusions and Recommendations

The environmental impact from food and drink consumption is dependent upon choice of products and a number of attributes associated with these products, their origin or people's behaviour concerning food and meals. Different aspects of Swedish food consumption are presented below. For more detailed reasoning and conclusions on different foodstuff groups, see the respective chapter.

9.1 Product Choice

Within the food groups treated in this report, some general conclusions can be drawn about environmentally sound choices:

Fruit and vegetables

- Increase consumption of fruit and vegetables
- Adapt consumption to the Swedish season
- Increase the proportion of Swedish apples
- Increase the proportion of Swedish root vegetables
- Source perishable fruit and vegetables from relatively local and regional areas
- Reduce consumption of bananas, citrus fruits and grapes
- Increase the proportion of organically produced fruit and vegetables
- Avoid products freighted by air and long-distance road transport

Cereals, rice and potatoes

- Use primarily domestic cereals
- Do not increase rice consumption
- Increase the proportion of potatoes from relatively local and regional areas

Legumes

- Increase the amount of dried legumes
- Increase the proportion of domestically produced legumes

Meat and dairy products

- Decrease total meat consumption
- Increase the proportion of domestic products
- Increase the proportion of meat and milk produced by domestic feed
- Concerning beef and lamb: increase the proportion based on grazing and roughage

- Concerning beef and lamb: increase the proportion of natural pasture-based production
- Concerning beef and lamb: increase the proportion of meat from combined milk and meat production

Edible fats

- Increase the proportion of domestically produced and domestically processed rapeseed oil
- Decrease the proportion of palm oil
- Decrease the proportion of olive oil
- Concerning butter: increase the proportion of butter from cows that consume an increased proportion of domestic feed

In general, it can be said that animal-based products have a greater climate impact than plant-based foods. The products can be ranked according to increasing climate impact, expressed per kg of product, as follows: coarse vegetables, onions, potatoes and legumes < cereals (whole grain, flour, bread) < rapeseed oil and olive oil < chicken < vegetables in heated greenhouses < pork < beef and milk in combined production < beef in specialist meat production.

Vegetables grown in greenhouses heated with renewable fuels generate significantly less climate impact than those grown in greenhouses heated with fossil fuels. Among conventional products, those grown in greenhouses have significantly less adverse effect on the environmental quality objective *A Non-Toxic Environment* than field-grown vegetables.

When cooking and other human behaviour is added, the picture of climate impact becomes more complex.

An increase in fruit and vegetable consumption and vegetable protein consumption at the expense of meat consumption would be environmentally advantageous. In addition to the environmental benefit, it would contribute to meeting the National Food Agency's current recommendations on increasing consumption of fruit and vegetables and legume protein. In the first instance, consumption of imported meat should decrease to the benefit of an increased share of domestic grazing animals and animals raised on a large amount of roughage. These contribute positively to the environmental quality objectives *A Rich Diversity of Plant and Animal Life* and *A Varied Agricultural Landscape*. By reducing total meat consumption, the climate impact is reduced and scope is created to meet more environmental quality objectives, although pork and in particular chicken have a lower climate impact per kg meat than beef. In further discussions about the balance between different species of animals, it is important to remember that monogastric animals are raised on feedstuffs that can go directly to human consumption, while ruminants can use land that is not suitable for the cultivation of crops for human consumption.

One cannot ignore the fact that the Swedish products studied in this report generally perform better from an environmental point of view than imported products. This is due among other things to the generally lower use of chemical plant protection products. The Swedish electricity mix is also environmentally advantageous. Furthermore, total transport distances are in most cases shorter than those of imported goods. Sweden does not have extensive acreages of monocultured crops and, in addition, there is a shortage of farmers and grazing animals, while in many of the countries from which we import food there is great pressure on arable land. This is important for the environmental quality objectives *A Rich Diversity of Plant and Animal Life* and *A Varied Agricultural Landscape*. Concerning these environmental quality objectives, cultivation is positive in Sweden, while it is negative in countries which produce large-scale monocultures for a large export market. In areas where arable land is in short supply, farmers often compensate for this by increasing their external inputs (such as fertilisers, plant protection products and more intensive production), which also increases the climate impact. Note that the term monoculture in this report is used in a wider sense, in that it also refers to situations where the same crop is cultivated on large acreages, that is in monoculture at the landscape level.

Some of the aspects listed above probably also apply to countries such as Norway and Finland, for example. That which is regarded as local/regional can therefore vary slightly with the product. For example, locally produced potatoes refers to an endeavour to have as locally produced potatoes as possible. In the example of western Sweden, this may mean that foodstuffs produced on the other side of the border in Norway can be equally relevant as those from east Sweden. Transport by air and road to the Swedish border adversely contributes to the environmental quality objective *Reduced Climate Impact*. The fact that society's entire transport requirement needs to be reduced (Klefbom, 2008; Environmental Objectives Council, 2008) also justifies an increased proportion of short-transport goods.

Another aspect of proximity to production is transparency, since it is easier to have insight into production and exert control closer to home.

The fact that an increased proportion of food from the local or regional area would be environmentally advantageous also agrees with conclusions by British studies cited in this report concerning British food consumption.

Generally, organic products seem to contribute more than conventional to the environmental quality objectives *A Varied Agricultural Landscape* and *A Rich Diversity of Plant and Animal Life*, among other things through their greater variation in crop rotations. In the case of *A Non-Toxic Environment*, organic products contribute unequivocally positively, which also has a positive impact on the above objectives. The fact that organic production systems also build on more local resource use results in organic products generally contributing more than conventional to the GRK Strategy. All in all, organic vegetable products appear to have lower or similar climate impact to conventional vegetable products (for example Nilsson, 2006; Nilsson, 2007). As regards the climate impact of animal-based products the picture is less clear-cut. In this context it is important to remember that farmyard manure which is produced in the conventional system also needs to be included in comparisons with organic systems.

9.2 Processed Products

As regards the environmental impact associated with processed products, there is a great need for knowledge. Provided that the processing (including raw material supply, buildings and machines, etc.) does not include the use of chemicals, it is mainly the environmental quality objective *Reduced Climate Impact* which differs markedly from the cultivation and manufacture of raw materials. The climate contribution of raw materials can in some cases be expected to have an influence, so that plant-based raw materials, which have significantly less climate impact than animal-based raw materials, can result in less climate impact. Climate impact is in this case entirely dependent on the types of energy carriers used in the processing and supply of raw materials.

Removal of water by drying is a very energy-demanding process, which can generate a large climate impact, for example in the manufacture of potato flakes, juice concentrate or tomato paste, depending on the fuel types used.

The climate impact from processing is dependent on the electricity mix in the country where the processing occurs. Processing within Sweden is advantageous from a climate point of view because of the climate advantages of the Swedish electricity mix. The relative advantages and disadvantages of the electricity mix in different countries manifest themselves to varying degrees depending on, among other things, the amount of electricity used, whether the processed product requires refrigeration/freezing during storage or may be stored at room temperature, mode of transport and transport distance, etc. In comparing equivalent products (for example processed potato products such as potato gratin) which are manufactured in similar processes, a European electricity mix which is produced with a large proportion of fossil fuels can consequently give rise to a significant climate impact.

Processed products often require more advanced packaging, which makes the choice of packaging design more relevant than for unprocessed products (apart from fragile fruits and vegetables), see Section 9.4 for more information.

9.3 Transport

The Swedish Environmental Objectives Council (Miljömålsrådet, 2007; 2008) indicates that transport is increasing, affecting the ability to achieve several environmental objectives. The Council also points to the importance of changing the present development in the transport sector. The Swedish Road Administration [now the Swedish Transport Administration] indicates that conveyance of goods must decrease and be optimised and further considers that the access to various functions to a greater extent must be provided via public transport, walking and cycling (Klefborn, 2008).

Since the climate impact of transport is a function of transportation time, fuel, distance and volume, transport-efficient packaging and modes of transport which use fuels that generate less climate impact are important. Rail transport that uses electricity is very energy-efficient. Transport by ship is also energy-efficient, but this depends on the type of vessel to a certain extent.

For perishables (with short intrinsic shelf-life), the risk of high losses is greater. Short transportation time thus becomes more important, which results in some long-distance perishable foodstuffs being transported by air. Since air transport gives rise to a particularly large climate impact, it would be environmentally advantageous to buy delicate products (such as berries and fresh legumes) from the local or regional area.

For products that must be transported in a controlled climate, such as fresh and frozen fruits and vegetables, meat and dairy products and ready meals, the significance of transport is accentuated. Frozen products often have higher density than chilled products, which means that more products can be transported per vehicle. By contrast, interim storage of frozen products consumes a large amount of electricity, as shown for pea burgers, for example. For frozen broccoli, lorry transport from Spain and transport by cargo ship from Ecuador both have a very large effect on climate impact. The significance of transport is also great for animal products and starch products. It is important to remember that despite long-distance transport by ship being considered energy-efficient, there is often additional transport by lorry to the port, which can have great significance for the climate impact. Local and regional food systems have great potential for streamlining through the coordination of transports (for example Ljungberg, 2006).

Transport from the point of purchase to the home has a very large effect on the impact of food consumption. In this context it is important that the consumer coordinates food purchasing with other activities and, when appropriate, cycles, walks and uses public transport.

For more reasoning on the connections between refrigeration, storage, transport and waste, see Section 3.3.7.

9.4 Waste, Losses and Rejects

Waste, losses and rejects are very important for the environmental impact from Swedish food consumption. Food that is not consumed has been produced and handled completely unnecessarily. The cumulative use of resources and the environmental impact of this are greater the later in the food chain the waste arises. Some waste is inevitable, such as potato peels, meat trimmings and such, but a very large part can be consumed.

The British Waste & Resources Action Programme (WRAP) estimates that approximately 6.7 million tonnes of food purchased in Great Britain are thrown away in households (Agra Informa Ltd, 2008; WRAP, 2008). Almost half this

waste is reported to consist of fruit and vegetables and most could have been avoided.

Waste, losses and rejects occur along the entire food chain, for example at harvest, during sorting and packaging after storage, in connection with transport, in restaurants, in retail and in households.

In connection with the work on the GRK Strategy, the Swedish Environmental Protection Agency draws attention to the problem of food being wasted along the food chain. A forthcoming report (Rytterstedt et al., 2008) by this Agency shows that in-store waste can amount to between zero and 25 percent of the total, with the lowest figures for milk and eggs and the highest for fruit, vegetables and delicatessen products. In food service institutions and the food wholesale sector, waste corresponds to 15-22 percent of the amount of food purchased and customer plate waste corresponds to half or more of this. Davis et al. (2006) report 10 per cent retail waste are for lettuce and bread, 2 per cent for potatoes and 1-2 per cent for pork chops and sausages.

Examples of waste in private households are around 20 percent for potatoes, 30 percent for lettuce and negligible waste for frozen sausages and pea burgers (Davis et al., 2006). Waste in the household is greatest for vegetables (13-28 per cent) and least for bread (3 per cent) (dairy goods up to 8 per cent, meat 17 per cent) (Rytterstedt et al., 2008). There is evidence that 10-20 percent of the food purchased by households is thrown away, excluding inevitable waste such as peel and bones. This is in addition to the waste occurring prior to the supermarket or restaurant, for example losses during handling, storage and transport. For example, around 25-30 percent bananas are discarded in the field and in the packaging plant due to aesthetic faults (blemishes, defects in colour and shape) (Lustig, 2004). The fact that fully edible products are discarded due to preferences for size or other aspects of appearance has also been shown for other products, for example 10-30 per cent for strawberries (Warner et al, 2005) and 20-25 per cent for carrots (Garnett, 2006). This problem is probably greatest for fresh goods.

The risk of high waste is greater for products with poor intrinsic shelf-life/keeping qualities, such as tropical fruits and berries, which are sensitive to pressure and bruising, or minced meat, which has large surfaces accessible to bacteria.

In view of the environmental impact of waste, it is reasonable to call into question the often excessive portions served in restaurants/cafeterias. These large servings give rise to waste which is very important from an environmental viewpoint, because it occurs late in the food chain.

Waste in households is linked to the design of the packaging. Packaging protects the contents and serves as a marketing tool and contribute to reduced waste, which reduces the environmental impact. It has also been shown that packaging can increase the climate impact considerably (Section 3.3.7). Packaging with minimised waste should have a large opening, be able to be placed upside down and be easy to reseal (Johansson, 2002). The environmental impact of the packaging is also linked to the amount of material per kg product and to the

choice of material. Improved packaging technology has probably also helped extend the distance and duration of food chains, through increased opportunities for storage and transport.

In today's society, consumers choose what they prefer to have for the moment rather than according to what is available in the refrigerator, resulting in spoilage of fresh produce before it can be consumed. This attitude to food means that there is a risk of households throwing out food which is actually perfectly good to eat.

Waste, loss and rejects are of course connected to attitudes and behaviour surrounding food (Section 9.6). The consumer can reduce waste considerably by eating the food purchased, that is by emptying the package and eating the food before it goes bad. The consumer can also contribute to reduced in-store waste by choosing a product closer to its 'Best before' date when the foodstuff is intended to be eaten within a short time, as this product would otherwise risk being discarded in the store.

It is important that the consumer has knowledge about how different foods should be stored in order to avoid impairing quality unnecessarily. It is also important that the consumer is careful when handling fresh produce, such as apples and potatoes (risk of bruising), lettuces (risk of squashing) and carrots (risk of cracks and breaks) upon purchase and during home transport so that its keeping quality is not impaired, which would increase waste. In-store, consumers should also be careful in handling produce that they do not purchase.

9.5 Discretionary Food

The food group referred to as 'discretionary food', that is food and drink that we do not need to eat for nutritional reasons, was not included in this report. Sweets, soft drinks, crisps and other snacks, biscuits, cakes, pastries, beer, wine and spirits are included in this group. This group contributes 20-25 percent of the total energy intake by Swedes and represents approximately 40 percent of household expenditure (Frykberg, 2005). Within this group, knowledge about the environmental impact is virtually non-existent.

From a dietary perspective, these foods take space from foods of higher nutritional value because people can only eat a certain amount of food per day. It can also be noted that the production of raw materials and the processing of these, for example refined sugar, glucose or fats, require resources and fuels as well as transport at all stages, which generates an environmental impact. Considering the fact that these products are also inferior from a nutritional point of view, it therefore seems reasonable to reduce the consumption of foods from this group in favour of more high value food where the environmental impact is easier to justify.

9.6 Behaviour Around Food

In addition to choices between products, advice concerning reducing the environmental impact associated with consumption of food can include behaviour concerning food. The importance of changes in behaviour, for example to reduce waste and rejects in households and restaurants, is pointed out by the Swedish Environmental Objectives Council (Miljöstyrningsrådet, 2008). To reduce waste, it is important that the consumer acquires knowledge about how different foods should be handled and stored, so as not to shorten their shelf-life.

Since transport to the home accounts for a large climate impact, it would be desirable to change food purchasing behaviour towards more public transport, cycling and walking. When a car is taken to buy food, the trip should be coordinated with other errands.

Cooking in the home presents considerable opportunities for reducing the climate impact, by the choice of cooking methods (e.g. stove top, oven) and by environmentally sound practices within cooking methods (e.g. keeping a lid on the saucepan, cooking on residual heat or using residual heat by wrapping the saucepan in a towel). Cooking larger batches of food at a time and saving the leftovers and extra portions for later also reduces the climate impact.

We have become accustomed to chilled products, which have climate impacts upstream in the food chain where sales, storage and transport involve chilling equipment. If we changed our behaviour to using more products which can be stored at room temperature, this would contribute to reducing the environmental impact, which in the long term would lower the need for refrigerator volume.

At restaurants, it would be desirable if consumers did not expect to be served in excess, an entire bowl of potatoes for example, where the leftovers are wasted, or very large portions are served to create a feeling of luxury.

At home and when eating out, it is environmentally important to eat as much of the entire animal and vegetable as possible. For animal products, this involves trying new dishes and learning to cook less popular cuts and offals and for vegetables it involves e.g. eating the stem of broccoli and not throwing away a whole pepper or apple because part of it is spoiled.

We have become accustomed to being able to choose what we want on every occasion, to instant gratification. This is evident for example in the high consumption of discretionary food. From an environmental perspective it would be desirable to challenge this 'party every day' mentality. This would mean checking what is in the fridge before deciding what to eat, for example. It would also include not eating air-freighted produce every day, despite thinking that these products are tasty. We have become accustomed to having access to all the products we want throughout the year. Here a change in behaviour towards not choosing the same meals all year round, but rather following the Swedish seasons, would be an important measure in reducing the environmental impact of Swedish food consumption.

9.7 Overall View and Collaboration

The way we consume food is de facto associated with considerable environmental impact from the production of inputs and production to infrastructure in society and handling in the household. This requires an overall view at different levels, at product level and at society level.

If we focus solely on improvements in individual products or among a range of products, we risk overlooking perspectives that are important at society level. This applies for example to transport, which can be seen to constitute a small proportion of the climate and environmental impact of an individual foodstuff. Despite this, transport has a very large environmental impact at society level (for example Klefborn, 2008; Miljömålsrådet, 2008). Moreover, road transport has environmental impacts that are currently not captured within LCA or other methods that focus on individual products or on the climate impact alone. This includes poor species diversity along road verges and roads acting as a barrier that prevents animals from moving around in the landscape (Forman & Alexander, 1998). Road networks also affect hydrological flows in the landscape and can contribute to erosion.

Food consumption should be viewed in a wider perspective where some types of consumption or food-related activities are associated with culture, tourism and recreation. In a still wider perspective, food consumption needs to be observed in the context of overall consumption (lifestyle), which spans different consumption sectors. In this perspective it is important to decide what is more necessary and what is relatively simple to change in the long and short term.

Decisions on different behaviours and needs within different components of consumption (media, vehicles, clothes, accommodation, food, etc.) are made by the individual consumer. For example, people who cycle to the supermarket or have a small house may consider it justifiable to allow themselves food products with a relatively higher environmental impact than someone who takes holiday flights or wastes heat in the home.

Apart from making existing production chains and sectors of society more efficient, consumers in Sweden inevitably need to reduce consumption of certain goods, namely those with high resource use and large environmental impact. As pointed out by Stevenson & Kehn (2006), in this process of change, it is very important that consumers, businesses and authorities work together to stimulate changes in behaviour which the individual consumer would otherwise have difficulty in making. For example, the consumer cannot create the conditions for an increased proportion of train transport. The National Food Agency's work on environmentally sound dietary guidelines is a very important part of this endeavour.

9.8 Need for Further Studies

This report exposed important gaps in knowledge where further knowledge and development are needed:

Specific knowledge about the cultivation of various products in the countries from which Sweden imports foodstuffs is needed. Data that do not derive from life cycle assessments are also very valuable for assessing the environmental impact of food consumption behaviour. Site-specific and product-specific knowledge of animal husbandry and cultivation measures (tillage, plant nutrient supply, mechanisation, plant protection), on-farm storage, etc. is valuable when drawing conclusions about products and the environmental impact of their consumption. The literature is often inadequate, which means that within this area there is a need for actual inventories.

Studies of variations between enterprises within the same region which produce similar products would provide data support for assessing the potential for improvement and contribute more reliable data on various environmental parameters (climate impact, plant protection, etc.). It is important here that inventories are made of actual systems and not based on literature studies.

Studies of environmental impact of processed products should cover both low processed foods (such as dietary fats and prepared vegetables) and high processed (such as beverages and ready meals), in order to allow more accurate assessments of processed products.

Studies of discretionary food are needed to provide data support for assessing the environmental impacts of reduction and replacement of these products.

Studies of the relationships between chilling, storage, transport and waste. Here it is important that inventories are made of actual systems and not based on literature studies. The links need to be pursued all the way to the consumer phase.

Studies on the amount by which different kinds of meat need to increase/decrease. More environmentally balanced meat consumption needs to be identified at national level and possibly at regional level.

Other environmental parameters, such as water use and eutrophication, also need to be studied.

Knowledge about land use associated with food consumption needs to be developed at product level and society level. Today we only include land use as area in primary production. Knowledge is lacking about land use in the remaining parts of the food chain (for manufacture of inputs, machines, buildings and transportation systems).

Carbon dioxide emissions associated with the cultivation of organic soils needs to be determined, with measurements for Swedish conditions. In the current situation very rough standard values are used.

An updated seasonal calendar for fruit, berries, root crops and vegetables should be developed.

Packaging that minimises waste, loss and rejects should be developed, without the packaging design and selection of materials overshadowing the gains in the reduction of waste.

It is important to have high degree of *transparency* in analyses included in studies, since this increases the usability of the results and the period over which they are used, as the user can decide whether circumstances have changed since the analysis was performed. It is also important to report how the different allocation methods influenced the results.

In conclusion, it is important to remember that environmentally sound food consumption is not about self-denial, but about striving for more environmentally balanced consumption. It is not a matter of excluding bananas, mangos or imported salad vegetables produced during the winter, for example, but rather of regarding them as a luxury for occasional rather than habitual consumption. It is a matter of more frequently eating a greater amount of produce that has a lower environmental impact and less frequently choosing produce with a relatively high environmental impact.

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