# Environmental impacts of eco-local food systems – final report from BERAS Work Package 2

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## Abstract

Longstanding initiatives with Ecological Recycling Agriculture (ERA) and local food systems in the eight EU-countries in the Baltic Sea drainage area were evaluated during the project period, 2001 - 2005. The surplus of nitrogen was 48 - 54 % lower per hectare and year on Swedish and Finnish BERAS-farms compared to the average (mostly) conventional agriculture (36 kg compared with 79 for Swedish and 38 kg compared to 73 for Finnish agriculture with the same animal density of 0.6 au/ha). There was no surplus of phosphorous from BERAS farms. The average surplus of nitrogen for all the 42 BERAS-farms studied in the eight countries was 38 kg. This can be compared to the average agriculture surplus of 56 kg for the eight countries today, which includes the low intensive agriculture in the Baltic countries and Poland. All BERAS-farms with an animal density below 0.75 au per ha have a surplus below 50 kg N/ha. By definition an ERA farm has integrated organic crop and animal production and near self-sufficiency of fodder production, i.e. an external fodder rate (EFR) of <15 %.

In both conventional and ERA agriculture an estimated 30 - 40 % of the nitrogen in animal exudates is lost as $NH_4$ to the atmosphere. This means that the calculated nitrogen leaching to ground water from ERA farms is 70 - 75% less than leaching from average Swedish agriculture (7 - 9 kg compared with 28 - 30 kg). The equivalent calculation for all eight BERAS countries gave a reduction of nitrogen leaching with 47 % on BERAS-farms compared to the studied average Baltic Sea agriculture which includes regions with, until now, very extensive agriculture.

Two possible agriculture scenarios were calculated for the BERAS countries: 1) conventional business-as-usual scenario where the Baltic Countries and Poland convert to the same structure and use of resources as in average Swedish and Finish agriculture, and 2) ERA scenario where agriculture in the whole Baltic Sea drainage area converts to ERA similar to the BERAS-farms. The conventional scenario 1 resulted in an increase of both nitrogen and phosphorus surplus in agriculture and a corresponding increase in the load to the Baltic Sea. The nitrogen leaching was calculated to increase by 58 %. The ERA scenario gave a *reduction* of nitrogen surplus from agriculture by 47 % and an elimination of the surplus of phosphorus.

The implications of four Swedish food basket scenarios for nitrogen surplus, global warming impact and consumption of primary energy resources were presented. Scenario 2, where all the food is produced on ERA-farms, would give a global warming impact of 800 kg $CO_2$-equivalents per capita and year compared to 900 kg in Scenario 1 with conventional agriculture. Scenario 3 with food from ERA-farms and local processing and distribution gave a global warming impact of 700 kg $CO_2$-equivalents per capita and year. Scenario 4 with food from only ERA-farms, more vegetable and less meat consumption and local processing and distribution gave a global warming impact of 500 kg $CO_2$-equivalents per capita and year. This is a reduction by about 45 % compared to Scenario 1. Also nitrogen surplus and consumption of primary energy resources were reduced to different degree for all alternative system settings. The results strongly indicate the importance of changing our food consumption patterns along with the changes in the food system necessary for reduced environmental impacts.

# Contents

# 1. Executive summary

This chapter gives a brief summary of the studies and the results presented in the report. Since this report from WP2 only covers the environmental assessment part of the project, a presentation of the whole project is first given.

## *BERAS – the project and cases*

The BERAS project is a research and development project. The overall goal of the project is to develop a knowledge base regarding possible means of significantly decreasing consumption of non-renewable energy and other limited resources and of reducing the negative environmental impacts at the same time as ecological, economical and sociological sustainability is enhanced in everyday living specially in the agriculture sector and food systems.

The work is based on practical case studies where initiatives have been taken to bring about lifestyle changes throughout the whole food system. These are primarily located in selected rural areas in the countries around the Baltic Sea and include primary agricultural production, processing, distribution and storage, consumption and waste management. The cases are complemented by selected reference farms in each country. These systems are characterised by ecological production (agriculture and processing), recycling and a minimisation of energy use for transport and other systems. The term “ecological” is used as a synonym to “organic”, and refers to a quality of food and agriculture production that uses neither chemical pesticides nor chemical fertilisers.

### Methodological approach

The BERAS project includes five Work Packages (WPs). The first WP (1) has promoted selected, already established local ecological food initiatives and recycling farms in each country and the exchange of experiences with other initiatives within and among the project countries. Obstacles have been identified and learning promoted through exchanges with others who have been involved with finding solutions to similar problems in their own country.

The second WP (2) has studied what environmental benefits can be achieved through local ecological food consumption, processing and ecological recycling agriculture (ERA), in comparison with conventional food systems. Energy use, greenhouse gas emissions, surplus and emissions of reactive nitrogen (air/water pollution) and surplus of phosphorus compounds of the agriculture-society system have been quantified and related to food consumption. Most of this work is done for Sweden and Finland, and to a more limited extent, the other BERAS countries. However the results are relevant for and can be utilised by all participating countries.

The third WP (3) assessed the possibilities for switching to ERA and the economic consequences of this by evaluating market aspects, economic consequences at the societal level and consequences from a natural resource economy perspective.

The fourth WP (4) looked at social consequences at the societal level including rural development and job opportunities. The fifth and final WP (5) will draw together the lessons learned from the other WPs and present an Agenda with recommendations for implementation and dissemination.

### Locations and criteria of activities

Studies of whole food systems were done in all EU member states around the Baltic Sea. These included: (1) Järna, Stockholm county and (2) Vassmolösa, Kalmar county in Sweden; (3) Juva, Mikkeli county in Finland; (4) Funen county, Denmark; (5) Bioranch Zempow Brandenburg in Germany; (6) Kluczbork and (7) Brodnica in Poland; (8) Raseiniai in Lithuania; (9) Organic farmer organisation in Aizkraukle district in Latvia; and (10) Pahkla Camphill village, Prillimäe in Estonia. Initially 35 reference farms were selected mainly for calculations of plant nutrient balances. They were considered to represent the main environmental and farming conditions as well as being situated in major food production areas in each country. The selection criteria of these BERAS-farms was that they used no chemical pesticides or fertilisers and they had a high degree of plant nutrient recycling based on a balance between animal and crop production and a low rate of purchased fodder.

### Dissemination

Farmers involved in the project have been continuously informed of results achieved and they have also received support for their activities. Dissemination of results has also been carried out through publications and adviser service organisations. Further dissemination of results and promotion of similar initiatives will be aimed at regional and local policymakers (especially those working with spatial planning), the food processing and distribution industry, and, at the grassroots level, consumers, farmers and small-scale actors in the food system, to encourage a transition to a more sustainable lifestyle in the agro-food sector.

## *BERAS Work Package 2 – environmental assessment*

The objective of BERAS Work Package 2 was to build up a knowledge base to promote reduced consumption of limited resources, reduced emissions of nitrogen and phosphorus compounds to the Baltic Sea and reduced emissions of greenhouse gases to the atmosphere, and to promote biological diversity within the food system. This was realised through evaluation and demonstration of the potential of ecological recycling-based agriculture, local and regional processing, distribution and consumption. Longstanding ERA initiatives in the participating countries were studied and promoted during the project period.

The evaluation of the potential for reduced losses of nitrogen and phosphorus was mainly based on plant nutrient balances carried out on ecological recycling agriculture farms (ERA-farms) with different agricultural conditions and production specializations in the eight BERAS countries. The nutrient balances gave information about the potential risk for leaching and the potential risk of nitrogen emissions to the atmosphere, assuming a steady state in the soil over a longer period of time (Granstedt *et al.* 2004). This was then compared to existing data averages for conventional agriculture. In the BERAS report 2 “Effective recycling agriculture around the Baltic sea” (Granstedt, et al. 2004), it was emphasised that the negative consequences of agricultural specialisation must be taken into consideration in the new EU countries that are about to introduce changes in their agricultural sectors. If this is not done, there may be, according to the final conclusions of the INTERREG IIIB BERNET project Baltic Eutrophication Research Network (Fyn's Amt, 2002), a dramatic increase in nutrient loads from countries like Poland and the Baltic states. As a reduction in the leaching and emissions of reactive nitrogen to the atmosphere by 50 % is the goal, then a reduction of the surplus of nutrients by more than 50 % is, over the longer term, necessary.

For determining the efficiency of recycling, Pentti Seuri developed a method for calculating primary nutrient efficiency The results of plant nutrient balances on farm level (i.e. farm gate balances) thus were complemented by this measure for nitrogen use efficiency, which shows how much more nitrogen is harvested in the yield than is imported in external resources. These calculated results were also supplemented with measurements of nutrient leaching on three farms. To give a wider assessment, a scenario study of the conversion to a purely organic and nutrient self-supporting system of the whole agricultural system on the Danish island of Funen was performed.

The assessment of global warming impact and consumption of primary energy resources were performed for the Swedish BERAS-farms and compared to average agriculture. Also assessments of Swedish cases of local processing, distribution and consumption were made in this regard.

In order to relate these environmental studies to food consumption, food consumption profile (food basket) studies were performed in Järna, Sweden and Juva, Finland. Scenarios were developed to reflect the difference in the environmental impacts of conventional and alternative systems for agriculture, processing, and distribution for different food baskets. The alternative food basket (containing more vegetables and less and different kinds of meat compared to the conventional) were based on consumer surveys of environmentally conscious households in Järna and Juva.

Also the organic waste management was judged as an important part of the food system based on the assumption that a higher degree of recycling of nutrients would lead to reduced emission to water and to the atmosphere. The possibility of recycling wastes from local food processing, distribution and big institutional kitchens was studied in Juva and the implications of this discussed both for Juva and Järna.

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## Principles of ERA systems

The concept of ecological recycling agriculture (ERA) was presented in the BERAS-background report (Granstedt et al. 2004) as an alternative to conventional agriculture. ERA produces food and other agriculture products following basic ecological principles:

1. Respect for diversity of life
2. Use of renewable energy
3. Recycling of plant nutrients

Conventional agriculture damages biological diversity through use of pesticides, consumes too much non-renewable energy resources, emits greenhouse gases, consumes limited plant nutrient resources and emits too high levels of plant nutrients to the environment.

The separation of plant and animal production increased after 1950 and culminated in 1980 in Sweden, Finland and Denmark. During the same period more specialised forms of agriculture based on non-renewable energy and pesticides use were introduced. This separation and specialisation led to reduced recycling and increased surplus of nutrients. Examples of nutrient balances in the background report illustrate this as increasing linear flows of nutrients.

One good example of an ERA farm (or farms in close cooperation functioning as one farm unit) is Skilleby-Yttereneby farm in Järna presented in the background report (Granstedt et al. 2004). This farm is adapted to meet the food demands of European consumers. About 85 % of the farm land is used for fodder and animal production. Being self-sufficient in fodder production limits the animal density (number of animals per hectare). Also about 15 % of the farm land is used for production of cash crops. Very little external input of nitrogen is needed due to the higher degree of internal recycling within the system. Nitrogen requirements are covered through biological nitrogen fixation of mainly clover/grass leys. There is only a limited deficit of phosphorus and potassium in the input and output balance. The greater part of the minerals is recycled within the farm in the manure. The limited net export of phosphorus and other nutrients seems to be compensated by the withering processes in most soils and a recycling of food residues could further decrease these losses from the system (Granstedt, 2000).

In practice a variety of on farms conditions exist and it is difficult to find the ideal ERA-farm in reality. What is important is to set up limits for inputs of external resources which can be realised in practice. Such limits will necessitate high internal recycling with the potential to reduce nutrient losses as a consequence. Although the ideal ERA farm is totally self sufficient in fodder in reality some smaller amounts of imported inputs (seeds and fodder) are necessary. An external fodder rate (EFR) of 15 % of total fodder was used as criteria for selection of the BERAS-farms. Another criterion was that a part of the agricultural land be used for bread-grain or other cash crops for direct human consumption. Not all the selected farms fulfilled these conditions during the whole project time (2002-2004) and this will be further discussed together with the results.

The principal difference between conventional agriculture and ERA-farms on a system level is the degree of integration of crop and animal production on the farm. In conventional agriculture crop and animal production are more or less *separated between* different groups of farms which in addition often are concentrated in different regions. On ERA-farms animal and crop production are *integrated within* each farm unit. The BERAS project has compared these two systems (the separated conventional and integrated ecological system). These comparisons use the same average animal density for all the farms and assume human consumption of both animal and vegetable agricultural products. In Sweden this comparison was done with the help of a conventional food basket and an alternative food baskets based on more locally produced ecological foodstuffs and a higher than average vegetable content

The potential of reducing nutrient surplus and losses of nitrogen through ERA for the different conditions in the production areas in the eight BERAS countries has been evaluated.

## *Results and discussion*

### Nutrient balances – influence of production systems (Chapter 2, 3, 4)

Potential of ERA (ecological recycling agriculture).

The surplus of nitrogen was 48-54 % lower per ha and year on Swedish and Finnish BERAS-farms compared to average (mostly conventional) agriculture (36 kg compared with 79 for Swedish and 38 kg compared to 73 for Finnish agriculture with the same animal density of 0.6 au/ha and there was no surplus of phosphorous. For the 42 farms in the eight BERAS countries that were studied the average nitrogen surplus was 38 kg compared to the average of 56 kg for the eight BERAS countries. This 56 kg average included the low intensive agriculture in the Baltic countries and Poland. All BERAS-farms with an animal density below 0.75 au/ha have a surplus below 50 kg N/ha and can be defined as ERA-farms with animal production based on a minimum of 85 % own fodder.

If only losses to soil and water are considered in the calculations, BERAS-farms had a potential to reduce nitrogen leaching by 70-75 % compared to average Swedish agriculture (average N- leaching of 7-9 kg compared with 28-30 kg). The same calculation made for all the eight BERAS countries gave a reduction of nitrogen leaching with 44-47 % on BERAS-farms compared to the studied average Baltic Sea agriculture which includes regions with, until now, very extensive agriculture.

Two agriculture production scenarios were calculated for the BERAS countries – Scenario 1 conventional ‘business-as-usual’ agriculture where Baltic Countries and Poland convert their agriculture sector so it has the same structure and use of resources as Sweden and Finland and

Scenario 2 ERA agriculture where all agriculture in the Baltic Sea drainage area converts to ERA agriculture like the BERAS farms. The conventional scenario gave an increased surplus of nitrogen and phosphorus from agriculture. Nitrogen leaching was calculated to increase by 50 %. The ERA scenario gave a calculated *reduction* of nitrogen leaching from agriculture by 47 % and an elimination of the surplus of phosphorus. Phosphorus leaching is especially problematic in farms with a high animal density.

One scenario specifically for Funen County in Denmark was developed based on an earlier larger study to determine the effects of converting the whole of Denmark's agriculture to organic farming. When this conversion was done in accordance with ERA principles (total self-sufficiency in fodder and production that meets the food demands of Danish consumers) it gave, as did the scenario for the whole BERAS study region, a reduction of the nitrogen surplus close to 50 %. This was related to Danish conditions and corresponded to 35 kg N-leaching per ha and is close to a 50 % reduction compared to the situation in Denmark in 2002. In the scenario with no external phosphorous inputs the phosphorous balance was calculated to about -6 kg P/ha.

## Global warming and energy use (Chapter 5)

The global warming impact, measured in Global Warming Potentials (GWP) as $CO_2$ equivalents, is reported per kilo products exported from the farm and per hectare. In both cases the impacts were lower for the average BERAS-farm than for the average Swedish agriculture (20 and 16 % lower respectively). The main reason was the non-use of chemical fertilisers on the BERAS-farms. This resulted in both lower direct impact from fertiliser production and lower emission of nitrous oxide from soil (due to lower input of nitrogen). There are two main reasons why the difference between the average BERAS-farm and the average Swedish agriculture is not greater. The first is the larger share of ruminant animals on the BERAS-farms and their larger emission of methane compared to average Swedish agriculture that has a larger proportion of monogastric animals which emit very little methane. The second is the less intensive production per animal, making more methane emitted per kilo product compared to conventional production.

The consumption of primary energy counted per kilo product and per hectare is substantially lower on the BERAS-farms in average compared to average Swedish agriculture (47 and 43 % lower respectively). The most important reasons are the lower use of heating oil (for drying of grain), no use of imported fertilisers and the lower use of electricity.

Sub-studies describe how locally produced and consumed food in Järna, Sweden is transported, and how much fossil energy this transportation, packaging and direct energy in the local processing has used. The studies covered four food groups: vegetables, potatoes and root crops; milk and dairy products; bread; and meat. The products are collected from the producers and delivered to stores, schools and other large institutional kitchens in both the Järna area and in Stockholm (about 60 km away). Calculations were made of energy used per kilo of products delivered. Calculations were also made for both the global warming impact and the use of primary energy of these locally produced and consumed products and compared them to conventional products. For bread, vegetables and dairy products both the global warming impact and the primary energy use were lower than comparable conventional systems. However for meat this was not the case, mainly due to the long distances to the regional slaughter house.

## Biodiversity (Chapter 6)

The use of pesticides in the conventional agriculture in the BERAS countries during the last decade was compiled. The trends of increasing use of pesticides are a threat to biodiversity in the agricultural landscape. A conversion to ecological recycling agriculture, which uses no pesticides at all, would enhance biodiversity.

## Improving nutrient balances by waste management (Chapter 7)

An inventory was conducted in Juva municipality in Finland to determine the possibilities for recycling biowaste (organic waste) produced by local food actors back into agriculture. The food actors included in the study were food processors, grocery stores, schools, municipal kitchens, and private consumers. The research methods included waste flow and substance flow studies.

Alternative treatment processes for recycling biowaste nutrients and humus include composting and biogas treatment (centralized or small-scale treatment or co-digestion plants). The conventional treatment of biowaste and wastewater result in nutrient losses and most nutrients in the treated biowaste do not become available to plants. The composting process mainly affects the amount of nitrogen. The loss of nitrogen in composting can be as much as 50%.

From an environmental perspective, separate urine collection would be preferable to the conventional system. This would increase the amount of recyclable nutrients to fields and at the same time decrease emissions into water systems. In addition, phosphorous would be in a more usable form for plants and the risk of heavy metal contamination would be less compared to conventional sewage sludge.

The small scale farm level biogas plant established as a prototype in Järna was effective for recycling solid fractions of nutrients from the human food sector (local processors, ecological public kitchen), reducing emissions of greenhouse gases and providing a good control against contaminations of pathogens and harmful substances.

## Influence of consumption patterns (Chapter 8, 9)

Results from food basket surveys in Sweden and Finland

Our food habits are, unquestionably, important both for our health and for the environment. That is recognised as one of the starting points in BERAS.

The main objective of the consumer surveys was to put together realistic food baskets (consumption profiles) for a Swedish and a Finnish case, containing mainly locally and ecologically produced foodstuffs. The case studies were performed in Juva, Finland and Järna, Sweden – the same sites used for many other studies in the BERAS project. All households participating in this study buy more than average organic products, and more so in Sweden than in Finland.

The food consumption profile of the Järna households seems to follow the diets suggested in the Nordic Nutrition Recommendations (NNR, 2004) and in the S.M.A.R.T. project (CTN, 2004). These households buy a larger share of vegetables and less meat, less “empty” calories, more ecological food, more of the “right” vegetables (e.g. more legumes and root crops, and less lettuce and cucumbers) and food that is transported shorter distances, compared to the national average food consumed.

The effects of four different food system scenarios on nitrogen surplus, global warming impact and consumption of primary nutrient resources are presented. The scenarios are:

1. Average Swedish food consumption, average Swedish agriculture 2002-2004, and conventional food processing and transports
2. Average Swedish food consumption, ERA farms, and conventional food processing and transports
3. Average Swedish food consumption, ERA farms, and local (small-scale) food processing and transports
4. An alternative food consumption (e.g. less and different kinds of meat), ERA farms, and local (small-scale) food processing and transports

Scenarios 2 and 3 based on primary production on BERAS-farms and with the same total meat consumption (but with a higher share of ruminant meat) seem to have, for Sweden, an unrealistic acreage of arable land as a consequence of lower gross productivity and the larger fodder area necessary to produced ruminant meat. However, also the conventional system in Scenario 1 uses imports from farms outside Sweden (about 1 million ha) which is not included here. In Scenario 4, also based on BERAS-farms but with an alternative more vegetarian diet, the need of agricultural arable land decreased with almost 40 % compared to the situation of today.

Nutrient balances in Scenario 2 and 3 with food from only ERA-farms gave a reduction of the nitrogen surplus with about 35 % counted per capita. Scenario 4 gave a reduction with about 65 % per capita. Counted per hectare the reduction was 45 %, although the acreage needed was decreased from about 2.5 million ha to about 1.7 million ha.

Global warming calculations in Scenario 2 with food from only ERA-farms would gave a reduction of global warming potential with about 11 %. Scenario 3 gave a further reduction of about 11 % (22 % lower than Scenario 1). Scenario 4, with an alternative more vegetarian diet, gave a global warming potential of about 500 kg $CO_2$ equivalents per capita compared with 900 kg $CO_2$ equivalents per capita and year in Scenario 1 – a reduction with about 45 %.

The consumption of primary energy resources was reduced with about 40 % in Scenario 2 and 3 compared to Scenario 1. Scenario 4 gave a consumption of primary energy resources of 3 GJ per capita and year which is a reduction with about 60 %.

## *General conclusions*

Long standing initiatives with Ecological Recycling Agriculture (ERA) and local food systems in the eight EU-countries in the Baltic Sea drainage area have been evaluated during the project period.

The surplus of nitrogen was about 50 % lower per ha and year on Swedish and Finnish BERAS-farms compared to average (mostly conventional) agriculture. When including all the 42 farms in the eight BERAS countries that were studied the difference was less (32 %) due to the current low intensive agriculture in the Baltic countries and Poland.

There was no surplus of phosphorus on the average BERAS-farm indicating that the leaching of phosphorus from agriculture could be close to cero in ERA farming systems.

Nutrient balance calculations of a fully realistic scenario assuming that the Baltic countries and Poland convert their agriculture to resemble the average Swedish agriculture gave an increased nitrogen surplus with 58 %. An alternative scenario, assuming that all agriculture in the Baltic Sea drainage area is converted to ERA gave a *reduction* of nitrogen surplus from agriculture with 47 % and an elimination of the surplus of phosphorus.
A scenario study of the Swedish food system explored the impact of different system settings: conventional vs. ecological recycling agriculture; conventional large-scale vs. local small-scale food industry and transporting; and Swedish average vs. an ecological, local and more vegetarian food consumption. Nitrogen surplus, global warming and consumption of primary energy resources were reduced to different degree for all alternative system settings. The results strongly indicate the importance of changing our food consumption patterns along with the changes in the food system necessary for reduced environmental impacts.

## Acknowledgments

We warmly thank our colleagues, farmers and actors in the BERAS project around the Baltic Sea who have collected and prepared data and in different ways have contributed to this publication, including Daphne Thuvesson for her careful editing and help with the language. BERAS-project is implemented through financial assistance from funds of the European Community's INTERREG IIIB programme and the European Community's PHARE CBC Project Facility Programme and from National Funds in the BERAS countries respectively.

# 2. Plant nutrient balance studies

## *Background and challenges*

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This project focuses on the potential of reducing the nitrogen and phosphorus load to the Baltic Sea by increasing the efficiency of recycling within the agricultural system, according to the principles of organic farming with an integration of crop and animal production and self-sufficiency of fodder. The BERAS background report, Effective recycling agriculture around the Baltic Sea (Granstedt et al. 2004) gives an overview of the main objectives of the current project and the challenges to be met.

The countries around the Baltic Sea countries have made international commitments, within HELCOM and OSPARCOM, to halve their discharges of nitrogen and to reduce their discharges of phosphorus from human activities. These goals have not been achieved during the target period 1987-1995 and no improvements have been observed between 1995 and 2000 according to the Executive Summary of the Fourth Baltic Sea Pollution Load Compilation. Measurements in streams to the Baltic Sea show no significant decrease of the total load (HELCOM, 1998; 2004).

This BERAS project includes all countries within the Baltic Sea drainage area that are EU-members. This excludes the regions belonging to Russia and Belarus. The focus has been to reduce the loads of nitrogen and phosphorus to surface waters and the Baltic Sea. Well established ecological recycling model farms situated in areas representative of the main agriculture production conditions were selected, taking into account existing growing conditions, the risks of nutrient losses, and the proximity of watercourses, lakes and sea areas. Data collected from these farms has been used to document the extent to which such agriculture can reduce emissions.

Based on the analysis of data collected the ultimate aim is to propose possible structural changes in the agricultural systems that will maximize recycling and minimize losses of nitrogen and phosphorus compounds at regional and country level and for the whole Baltic Sea drainage area. This requires that the very different situations in the agricultural sectors of the countries taking part in this project are taken into account.

### Nitrogen and phosphorus load in the Baltic Sea drainage area

Total nitrogen input to surface waters within the Baltic Sea drainage area was 822 kt in the year 2000. Of this, diffuse sources (mainly agriculture) contributed 58% according to HELCOM (2004). The highest inputs were in Poland, Sweden and Finland (Figure 2-1 A). However, nitrogen load per capita and per hectare has been highest in Denmark, Sweden and Finland (Granstedt et al. 2004). These three Nordic countries also have a high nitrogen surplus in their agriculture compared to Estonia, Latvia and Lithuania (Figure 2-1 B) (Granstedt et al. 2004). The hypothesis was that this is a result of higher fertilizer usage and higher livestock density partly based on imported fodder in these countries.

The surplus, as the term is used here, is the difference between import and export from the agriculture and a part of that contributes to the nutrient load to the Baltic Sea.

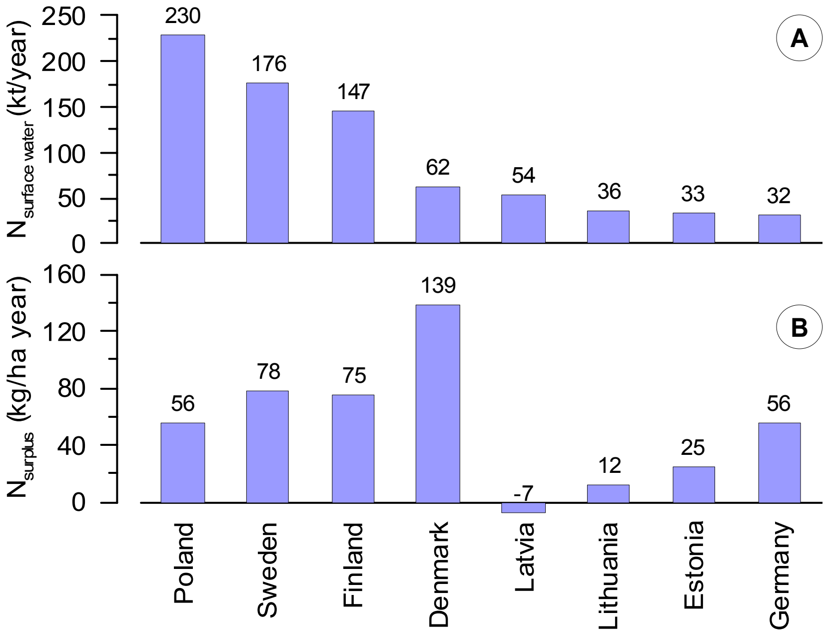

**Figure 2-1. Total nitrogen input to surface water (A) and nitrogen surplus in agriculture (B) in countries participating in BERAS. Data in (A) from HELCOM (2004) and data in (B) from Granstedt et al. (2004).**

The distribution of sources differs slightly in the different countries but the pattern is similar. In Sweden about 60% of the total nitrogen load to the Baltic Sea is anthropogenic and about half of the anthropogenic load originates from agriculture (Figure 2-2) (Brand and Ejhed 2002).

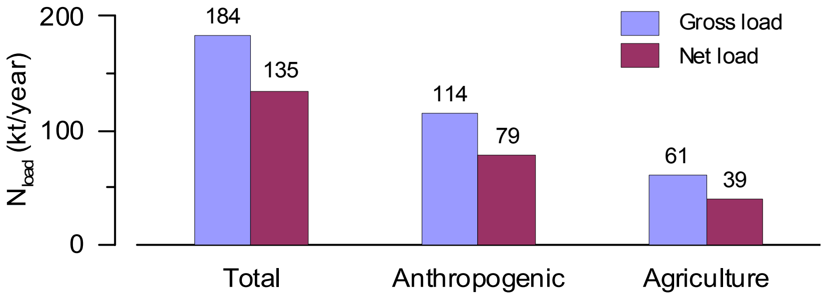

**Figure 2-2. Mean annual nitrogen load in Sweden for the period 1985-1999 (Data from Brand and Ejhed, 2002). Total – includes total load to surface water and directly to the Baltic Sea, Anthropogenic - includes all anthropogenic emissions (including all diffuse and point sources). Gross load is total load to surface water and directly to the Baltic Sea and net load is nitrogen load to the Baltic Sea after retention.**

An overall reduction of the nutrient load to the Baltic Sea by 50% is one of the nationally and internationally agreed environmental goals for the Baltic Sea Region (HELCOM 2004). This implies different strategies for the different countries. In countries with nutrient intensive agriculture like Sweden, Finland and Denmark loads have to be decreased. In countries with nutrient extensive agriculture like Estonia, Latvia and Lithuania the development of agriculture towards more nutrient intensive methods has to be prevented. The overall goal of the nutrient studies in the BERAS-project is to investigate the potential of ecological recycling agriculture (ERA) to reduce nutrient leaching from agriculture and contribute to the proposed 50% nutrient load reduction.

## *Material and Methods*

The study is based on agriculture plant nutrient balance calculations for each country as a whole both in total amounts and per ha. These values are representative for the average in each country and are compared to the selected BERAS farms in each respective country.

### Selected BERAS-farms

An ERA farm is defined as a farm (or farms with closed cooperation like one farm unit) with high rate of recycling of nutrients based on organic, integrated crop and animal production, with an animal density of < 0.75 au/ha and an external fodder rate (EFR) of < 0.15. ERA farms were selected in each country in order to evaluate their potential to reduce nutrient surplus and losses from agriculture in the Baltic Sea drainage area. The test-farms are representative for the main agricultural conditions and drainage regions in the area (Figure 2-3) and supposed to together produce an enough broad spectra of crops and animal products needed for human consumption in each country. Characteristics of the farms are presented in Appendix 1. The initial 35 farms were complemented with additional farms in Finland (the region of Juva close to Mikkeli) and in Sweden (Järna) for more detailed studies and to cover different types of agricultural production. In total 50 farms were studied. Some of the farms did not fulfil the preconditions for ERA farms and the consequences of this are discussed together with the evaluation of results.

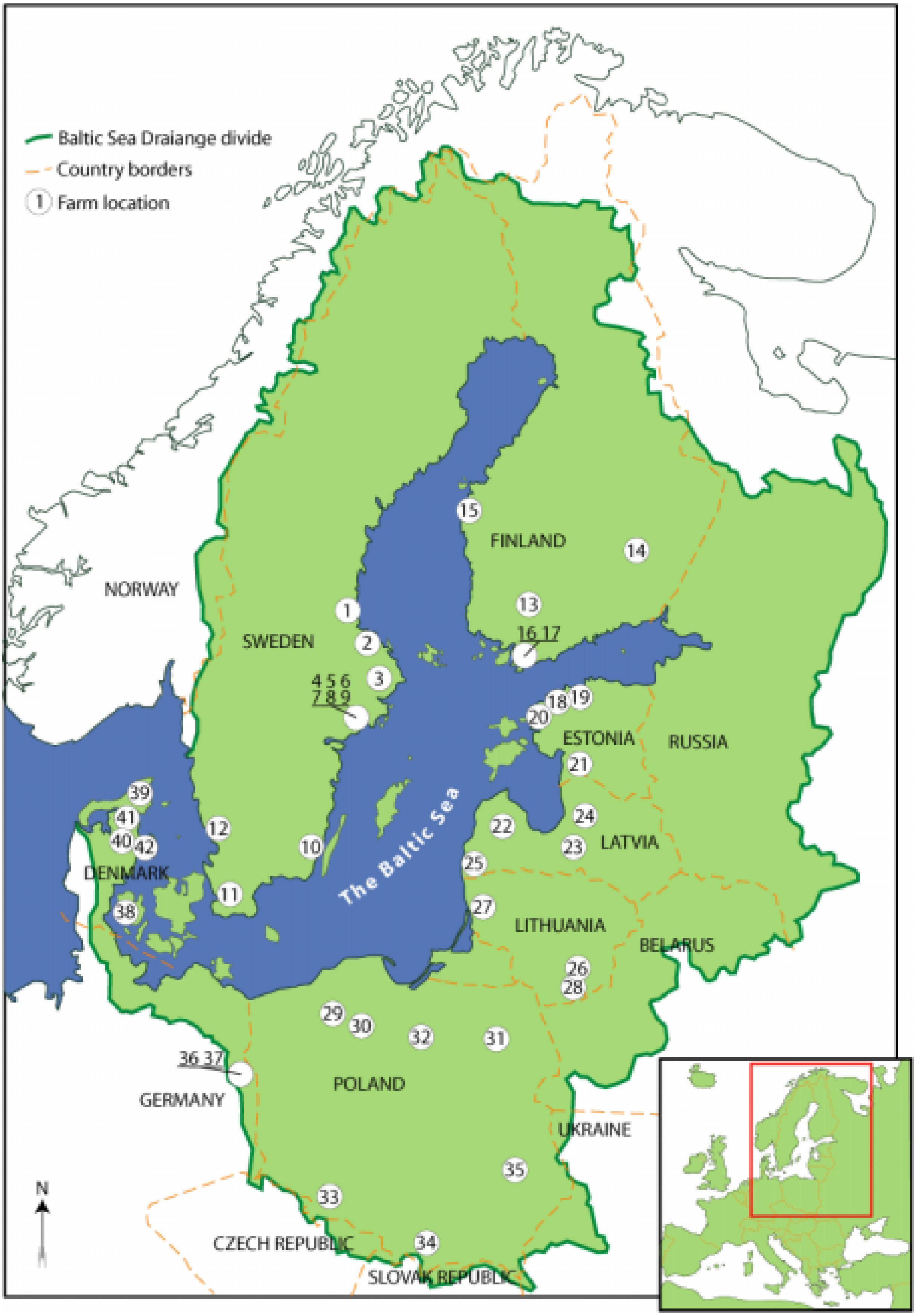

Figure 2-3. The Baltic Sea drainage basin with locations of farms included in BERAS.

### Field and farm gate balances

The methods for calculating nutrient balances follow those described in earlier publications (Granstedt, 2000; Granstedt et al. 2004) and are summarized below. The difference between input and output of plant nutrients is defined as surplus of plant nutrients and is the same as potential losses. For estimations of potential nutrient losses, plant nutrient balances can be calculated at field level (field balances) or for whole farms (farm gate balances).

*Farm gate balances* are based on the difference between the import (input) of fertilizers, imported fodder, nitrogen fixation, precipitation of atmospheric nitrogen and the export (output) of agricultural products from the farm. This method can also be used to calculate balances for larger systems such as administrative regions or drainage areas, e.g. the Baltic Sea drainage area.

*Field balances* are based on the difference between input and output of plant nutrients at field level using the amount of manure and fertilizers for input data and the amount of harvested crops for output data.

SCB (2002) in Sweden has regularly presented both types of balances. The farm gate balance for the whole of Sweden is based on import and output data. Similar methods have been used as in Granstedt et al. (2004) for calculations in the eight countries around the Baltic Sea. Field balances (referred to as surface balances by SCB) are based on information collected directly from the Swedish farmers.

### Nitrogen fixation and input through atmosphere deposition

An important part of the nutrient balances is the input through nitrogen fixation. The nitrogen fixation on the farms in Sweden, Finland (F-BERAS farms), Estonia, Latvia, Lithuania and Poland were estimated using the calculation programme for nutrient balances Stank 2:1 (Jordbruksverket, 1998) and the collected data on yield level and clover percent in the clover grass fields. The clover percentage has been estimated in the field and combined with sampling to calibrate the estimate. In each country this has been done by the same person every year nutrient balances were calculated in that country. The figures for nitrogen deposition are based on measurements of wet and dry deposition made by the Environmental Research Institute for the respective years according to Granstedt (2000).

The estimation of nitrogen fixation in Denmark and Germany has been done according to similar methods adopted and used in these countries. For this reason the estimated surplus of nitrogen can deviate from the other countries, how much should need a special comparing study. In Denmark nitrogen fixation has been calculated as in Kristensen et al. (1995) and Nielsen & Kristensen (2005) and in Germany as in Stein-Bachinger et al. (2004).

## *Results of plant nutrient balances in the BERAS countries*

### Sweden

*Artur Granstedt, The Biodynamic Research Institute, Järna Sweden*

The average results of nutrient balance calculations for 2002 - 2004 at farm level are presented in Figure 2-5. The calculations for nitrogen are presented for all the three years separately in Figure 2-4. For more detailed results see Appendix 2. The average nitrogen surplus on the BERAS farms was in the range 35-37 kg N per ha and year during the study period (Figure 2-4). When data from all 12 BERAS farms was added together and divided with total area of the BERAS-farms, the average surplus of N was 39 kg per ha and year. This can be compared to the average for Swedish agriculture which has been calculated to 79 kg per ha and year for 2000-2002 (Figure 2-6).

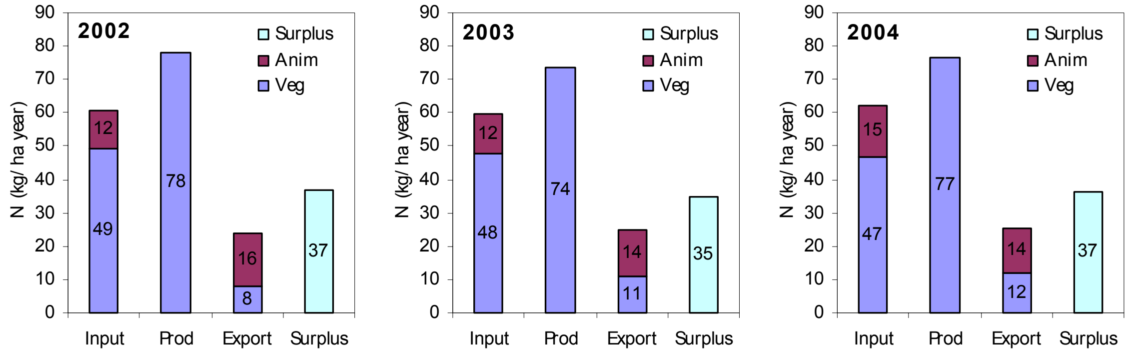

**Figure 2-4. Average input, plant production, export and surplus of nitrogen (N) on the BERAS-farms in Sweden for the years 2002, 2003 and 2004.**

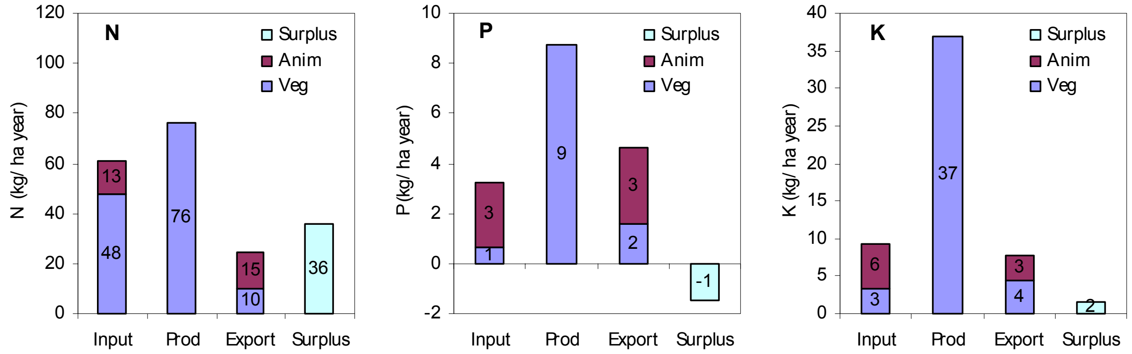

**Figure 2-5. Average input, plant production, export of farm products and surplus of nitrogen (N), phosphorus (P) and potassium (K) on the BERAS-farms in Sweden 2002-2004.**

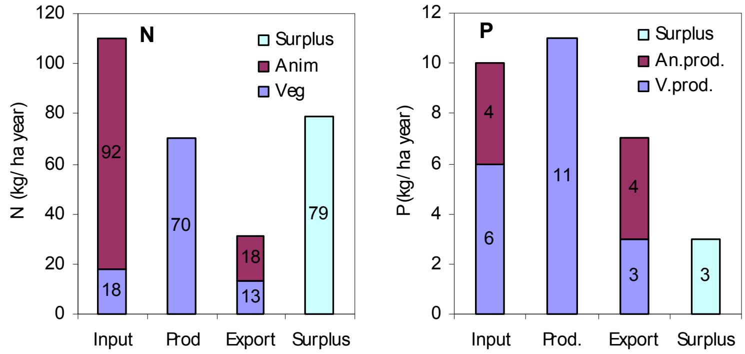

**Figure 2-6. Average input, plant production, export and surplus of nitrogen (N) and phosphorus (P) for Swedish agriculture 2000-02 (Granstedt et al. 2004).**

The calculated crop production in terms of N is higher but food production is about 25 % lower in ERA than in conventional agriculture. This can be explained by the higher portion of ruminant clover-grass-based animal production. Conventional agriculture is dominated by grain-converted meat production which has a smaller ratio between input of fodder protein and output of animal protein. Nitrogen surplus is more than 50 % lower per hectare on Swedish BERAS-farms which have the same animal density of 0.6 au/ha but a slightly lower share of animal products (in terms of N) in the total production.

The variation between the Swedish BERAS farms was rather high with a lower N-surplus on farms with low animal density than on farms with a higher animal density (Figure 2-7). All farms with an animal density below 0.75 au per ha and which produce at least 85% of all fodder on the farm (i.e. their external fodder rate EFR is less than 15%) fulfil the criteria for an ERA farm. All of these had a surplus below 50 kg N/ha.

The lowest N surplus was found on the more extensive meat and cereal producing farms in Oxsätra and Håknäs. The highest N surplus was found at the intensive dairy farm Skogsgård which did not fulfil the conditions for an ERA-farm according to the definition above.

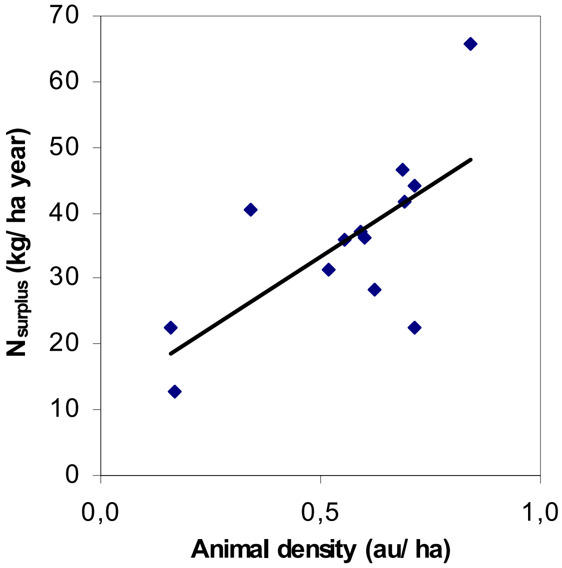

**Figure 2-7. Average animal density and N-surplus 2002-2004 for the Swedish BERAS-farms.**

The External Fodder Rate (EFR) and surplus of nitrogen per ha and year for the three years period for the BERAS-farms is presented in Figure 2-8. Two farms, the dairy farm, Skogsgård and the pig farm Davidsta, did not quite fit the definition of an ERA farm. Their EFR was more than 15 % (but less than 20 %). They had a surplus of 66 and 44 kg N per ha and year respectively, diverging more or less from the average value of 36 kg N/ha for all farms.

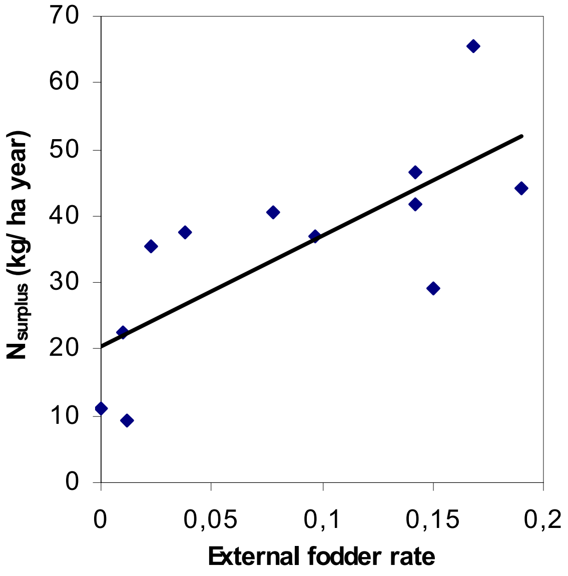

**Figure 2-8. External fodder rate and N-surplus 2002-04 for the Swedish BERAS farms.**

The surplus was highest for the dairy farm Skogsgård. Already at the beginning of the study period this farm had too high an animal density to fulfil the criteria for an ERA-farm. During the study, the farms' animal density increased to an average of 0.9 au per ha. This resulted in an average surplus of 70 kg N per ha (Figure 2-9).

The pig farm Davidsta evolved in the opposite direction during the study period decreasing both the animal density and EFR. This resulted in a lower N-surplus (Figure 2-9).

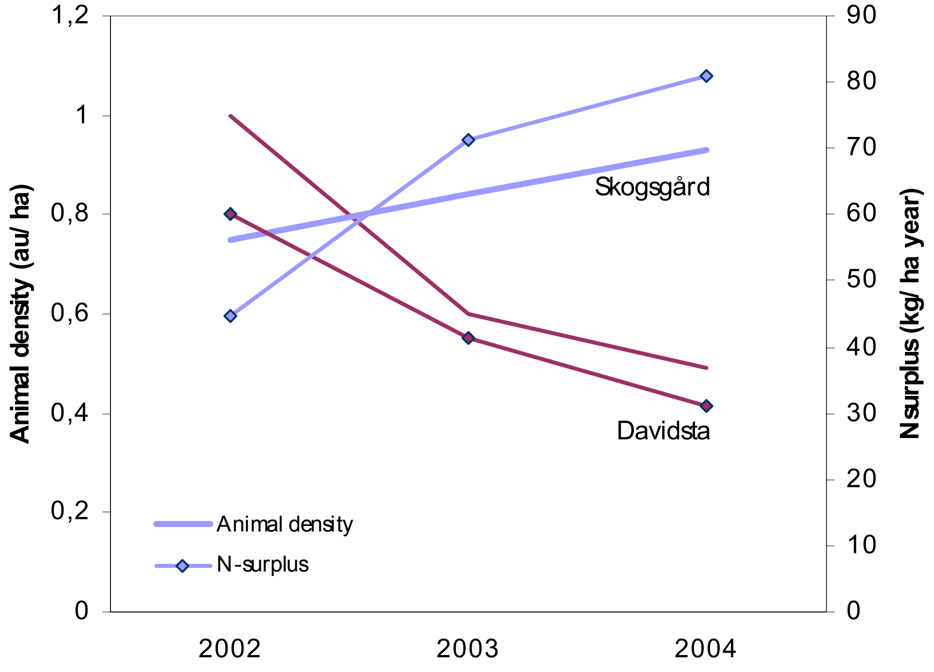

**Figure 2-9. Surplus of nitrogen on two farms with different animal densities. The dairy farm Skogsgård is characterised by an increasing N-surplus, increasing animal density and increasing use of purchased fodder (EFR: 0.08; 0.20; 0.21). The pigfarm Davidsta is characterised by decreasing N surplus, decreasing animal density and decreasing use of purchased fodder (EFR: 0.24; 0.16; 0.18).**

The relation between animal density and surplus of nitrogen is illustrated in Figure 2-10. On the BERAS dairy farms with low animal density (0.65 au/ha), the average N-surplus was 42 kg per ha. In conventional agriculture on more specialised dairy farms, based on data from 608 dairy farms (Myrbeck 1999), the average N-surplus was 131 kg per ha. Unpublished data from the Swedish action program "Greppa Näringen" based on approximately 6000 nutrient balances give nearly the same average with a N-surplus of 50 kg /ha on crop farms and 133 kg per ha on dairy farms.

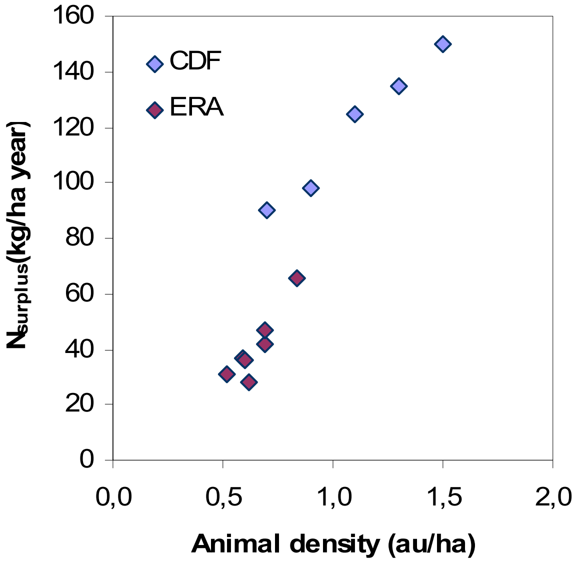

**Figure 2-10. The BERAS dairy farms (ERA) with a low animal density had an average 42 kg N surplus per ha, compared to an average of 131 kg N surplus per ha on 608 conventional dairy farms (CDF) divided in five animal density groups published by Myrbeck (1999).**

Myrbeck's study published in 1999, which compiled data from more than 1000 conventional farms (both dairy and specialised crop farms), is to date the largest study performed. It is representative for Swedish agriculture and also provides a good basis for comparison with the three BERAS-study years 2002-2004 since the total surplus of plant nutrients in CA is on the same level during these two study periods. Figure 2-11 shows the lower N-surplus from four groups of BERAS-farms compared to four corresponding groups in conventional agriculture. The lower N-surplus on BERAS-farms is associated with lower animal density and consequently lower need of external fodder input.

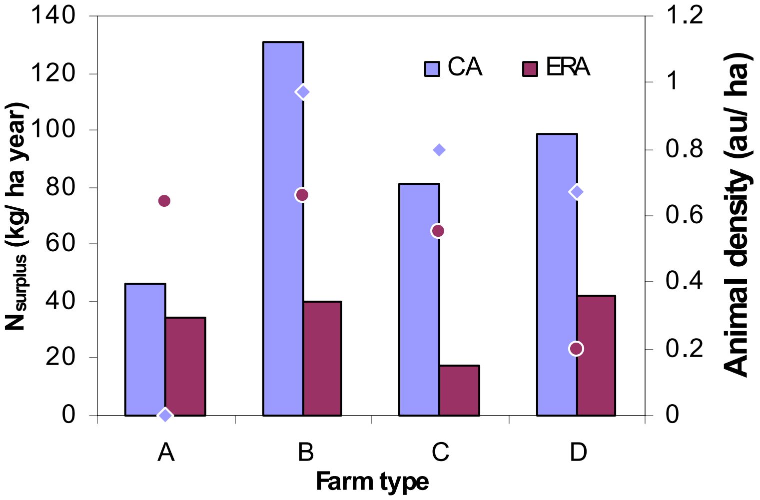

**Figure 2-11. Surplus of nitrogen in four groups of BERAS-farms (ERA) and corresponding conventional farms (CA) (Myrbeck 1999). Dots show animal density. A - Mixed production with vegetables (2 farms), B - Milk, meat and cereals (6 farms), C - Cereals and ruminant meat (2 farms), D - Pork, poultry, egg and cereals (2 farms).**

Field balances for the BERAS farms have been calculated based on the data collected. Field balance = Farm gate balance minus aerial losses in stable and manure storage. The calculations have been made with two alternative levels of $NH_4$ emissions from the animal production and manure management. One calculation is based on an estimated amount of N in manure assuming an emission of 30 % of the difference between fodder consumption and animal production, the other is based on an assumed emission of 40 % (Figure 2-12). This calculations gave a N-surplus of 20 and 14 kg per ha respectively. This can be compared with the calculations for the average for the whole of Swedish agriculture that were based on the same assumptions and that gave an N-surplus of 68 and 58 kg per ha respectively. Assuming a field drainage leakage of 48 % the field balance surplus gives a theoretical nitrogen leakage of 9 and 7 kg per ha respectively. This can be compared to calculations for the average for the whole of Swedish agriculture that, assuming the same field drainage leakage, gave an N leakage of 30 and 28 kg per ha respectively. This gives a reduction of 70 and 75% nitrogen leaching respectively on BERAS farms compared to the average on conventional Swedish farms.

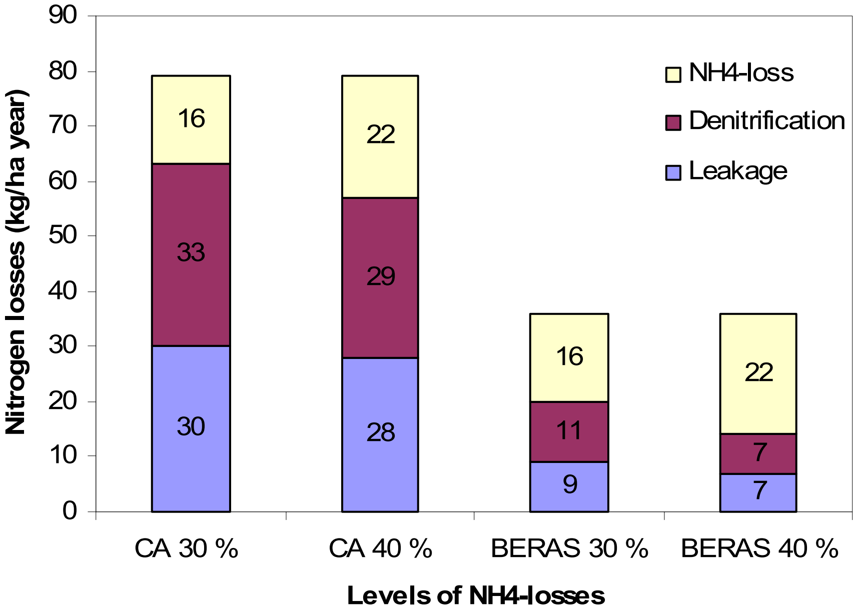

**Figure 2-12. The distribution of N losses of the calculated N surplus for Swedish average agriculture and the BERAS-farms with two different manure handling systems (resulting in 30 and 40 percent ammonia losses from the animal exudates respectively).**

## Finland

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*Pentti Seuri, MTT Agrifood Research Finland*

The Finnish study was conducted on five BERAS-farms (called F-BERAS-farms); two in the cereal-dominated south, one in the centre (Tampere), one in the animal-dominated north-west (Österbotten) and one in the east (Juva). In addition a more detailed study of 8 ERA farms located in the Juva region (called J-BERAS-farms) has been carried out.

The average nitrogen surplus on the five F-BERAS-farms range between 32-43 kg N per ha and year during the study period (Figure 2-13). For more detailed results, see Appendix 2.

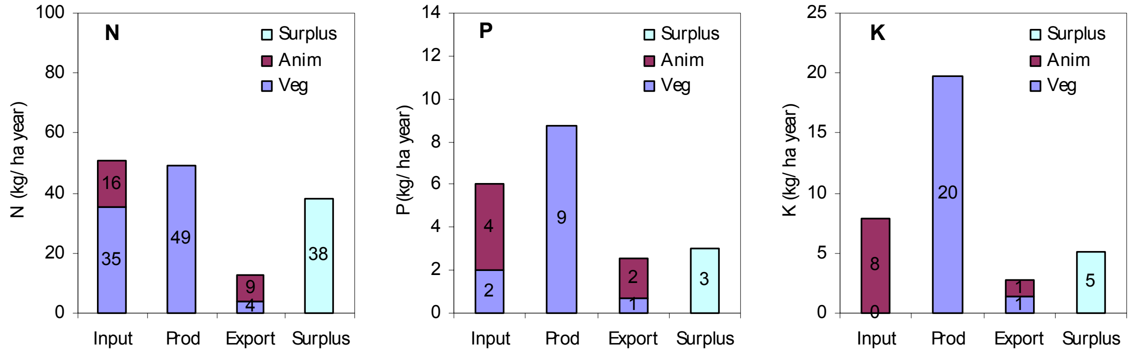

**Figure 2-13. Input, plant production, output of farm products and surplus of nitrogen (N), phosphorus (P) and potassium (K) on the F-BERAS-farms in Finland 2002-2004.**

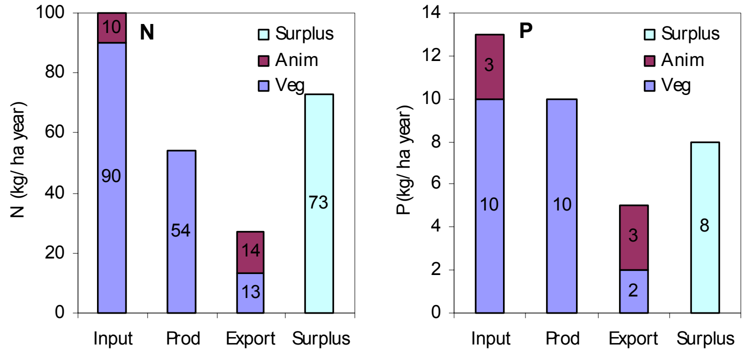

**Figure 2-14. The input, plant production, export and surplus of nitrogen (N) and phosphorus (P) in Finnish agriculture, averages per ha and year 2000-2002 (Granstedt et al. 2004). Mean animal density was 0.6 au/ha.**

The average annual nitrogen surplus on the five Finnish F-BERAS-farms ranged between 32-43 kg per ha during the study period with a range among the farms from 27 to 52 kg/ha. This gives an average surplus of 38 kg N per ha and year which can be compared to the calculated average for Finnish agriculture of 73 kg per ha and year for the period 2000-2002 (Figure 2-14). The surplus of nitrogen in average Finnish agriculture is twice that on Finnish F-BERAS-farms with the same animal density (0.6 au/ha).

The calculated average nitrogen fixation including deposition was 30 kg per ha and the calculated nitrogen in produced fodder was 49 kg per ha.

The surplus of P on F-BERAS farms was 3 kg per ha (Figure 2-13) compared to the average 8 kg for the whole of Finnish agriculture (Figure 2-14). Most of the F-BERAS farms have a deficit for P in the balance but one farm with surplus makes average surplus. The lower surplus of P give a lower risk for losses of P compared to average agriculture.

Crop production in terms of N on F-BERAS farms was only nine percent lower but food production (crop and animal products) was more than 50 % lower. This can be explained by the higher portion of ruminant clover/grass-based animal production compared to conventional agriculture that is dominated by the more surface-effective grain converted to meat production.

The variation between the farms was rather high. A lower N-surplus was found on farms with a lower animal density and a higher on farms with a higher animal density (Figure 2-15). All

F-BERAS-farms with an animal density under 0.7 au per ha show an N-surplus lower than 52 kg /ha.

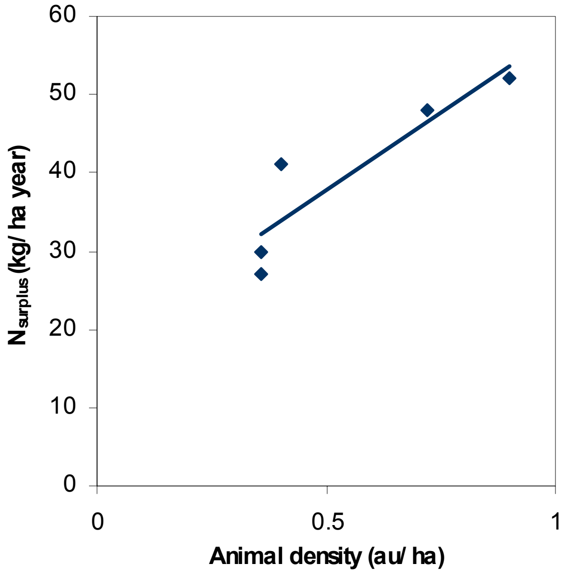

**Figure 2-15. Average animal density and surplus of nitrogen per ha and year for the three years period for all the Finnish F-BERAS-farms.**

## The Baltic countries – Estonia, Latvia and Lithuania

*Artur Granstedt, The Biodynamic Research Institute, Järna Sweden*

The selected BERAS-farms in the Baltic countries were studied during three years in Estonia and two years in Latvia and Lithuania. Nitrogen and phosphorus balances on these farms are presented in Figure 2-16. The surplus of nitrogen is higher on these farms than on the average agriculture in Estonia (Figure 2-17). The average agriculture in Estonia is, as is also the case in Latvia and Lithuania, very extensive. The use of artificial fertilisers is very low compared to Sweden and Finland. The statistics for nutrient balances in Latvia and Lithuania seem very unreliable due to considerable areas of agriculture land not being used for production. For this reason they have not been presented here. The interpretation of the data is further complicated by the fact that organic agriculture is producing under extraordinary circumstances. Large areas of land are not being optimally used and there is a weak correlation between field production and harvested yield and sales of animal and vegetable products from these farms. Some farms are not being 'managed' and the harvest is more or less what the land and soil can give. The whole agriculture sector is characterised by both technical and social problems. For this reason the statistics presented are very difficult to interpret. They reflect the unstable situation in the country rather than any real difference between what has been classified as BERAS and conventional agriculture.

The relation between animal density and surplus on the eleven studied farms is presented in Figure 2-18. It shows a tendency for a higher N-surplus on farms with higher animal density. Animal density is low on organic farms as it is on average farms. There was a dramatic decrease in the animal production after 1990 in the Baltic countries. This was a result of the extraordinary low prices for agricultural product after the collapse of the Soviet Union which had previously been the most important market.

The extreme N-surplus on three of the BERAS farms is a result of the high calculated nitrogen fixation in relation to low utilized yield (export). If these three farms are excluded from the calculations then the relation between N-surplus and animal density is more representative for these countries (the lower regression line in Figure 2-18). The average N-surplus is then 31 kg N per ha and the animal density 0.3 animal unit per ha.

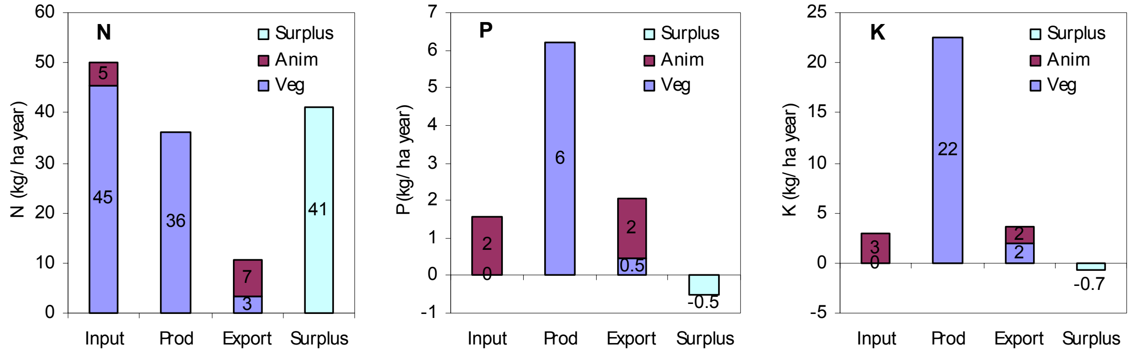

**Figure 2-16. Input, plant production, export of farm products and surplus of nitrogen (N), phosphorus (P) and potassium (K) on the BERAS-farms in the Baltic countries 2002-2004.**

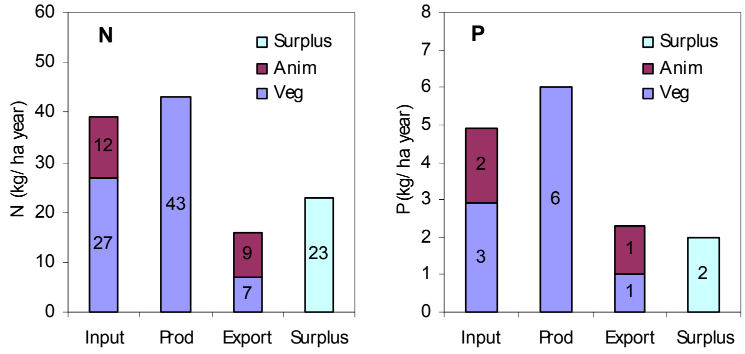

**Figure 2-17. The input, plant production, export and surplus of nitrogen (N) and phosphorus (P) in Estonian agriculture, average per ha and year 2002.**

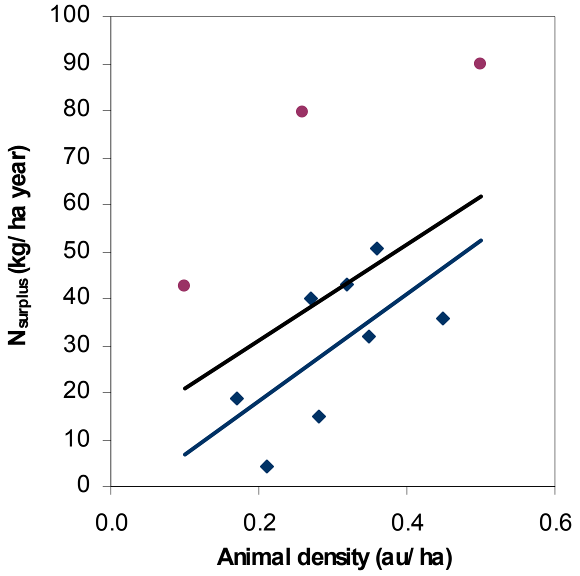

**Figure 2-18. Average animal density and surplus of nitrogen per ha and year for the three year period for the Baltic countries' BERAS-farms. The higher (black) line includes all the BERAS farms in the Baltic countries. The red circles represent the three farms which are excluded in the lower (blue) regression line.**

## Poland

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*Jaroslaw Stalenga, Institute of Soil Science and Fertilization, Pulawy, Poland*

In Poland 7 farms were selected, covering the main farming conditions in the country. Data was collected during two years, 2003-2004. It was only in 2005 when extra project resources were made available that it was possible to collect the necessary data to make fixation estimations. These seven farms are very well-known and considered to be representative for the various farming conditions. A special study on 20 organic farms in the district of Brodnica was done during 2002. The results of this study have been published in Polish by the BERAS project (Kus, Kopinski, Stalenga and Tyburski 2004).

The average nutrient surpluses of the Polish BERAS-farms are presented in Figure 2-19 . These can be compared to the average surpluses for average Polish agriculture presented in Figure 2-20. The calculated nitrogen surplus of 32 kg per ha on BERAS farms was 45 % lower than the average nitrogen surplus of 57 kg per ha in Polish agriculture as a whole. The export of phosphorus in agricultural was three kg higher than the input (3 kg deficit) on BERAS farms compared to the average Polish agriculture with a surplus of 19 kg P per ha. Large areas of agriculture land in Poland are managed very extensively. However some areas, especially in the northwest, are managed more intensively and are more like agriculture in Western Europe. The high level of P-fertilisers use is note worthy. Such an over-optimal use of P-fertilizers was earlier practiced in Sweden and Finland but this has decreased during the past 20 years.

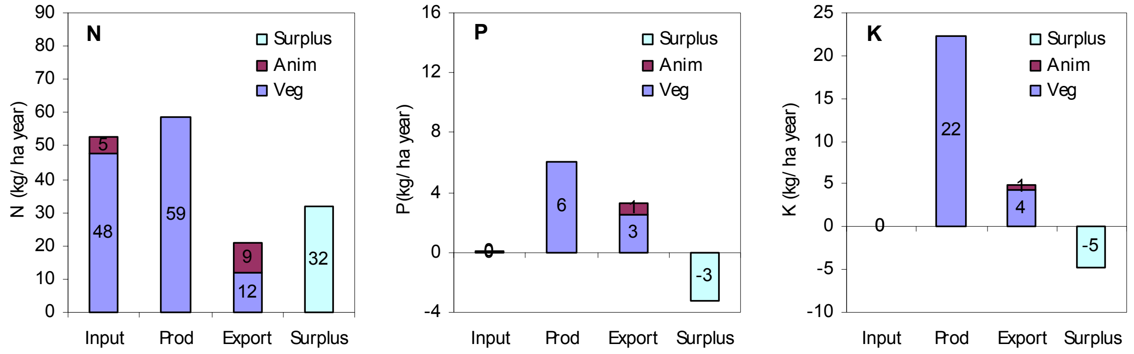

**Figure 2-19. The input, plant production, export and surplus of nitrogen (N), phosphorus (P) and potassium (K) on the seven BERAS-farms in Poland 2003-2004. Animal density 0,6 au/ha.**

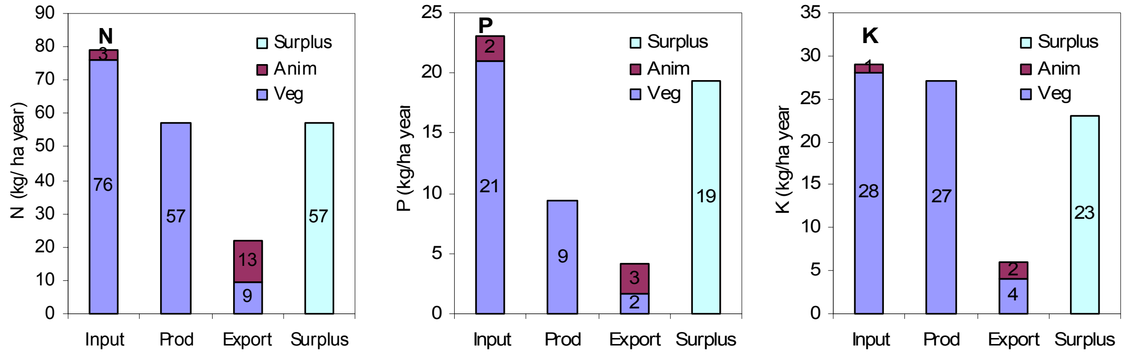

**Figure 2-20. The input, plant production, export and surplus of nitrogen (N), phosphorus (P) and potassium (K) in agriculture in Poland 2000-2001. Animal density 0,6 au/ha**

## Germany

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Plant nutrient balances of the two selected BERAS-farms in the Oder drainage area in Germany are presented in Figure 2-21. These figures can be compared with the data for the region of Märkisch-Oderland shown in Figure 2-22. The very low N-surplus on the two German BERAS farms of 16 kg per ha can be explained by the very low animal density which is representative for the east part of the German Baltic Sea drainage area. The N-surplus is only 22% of the surplus in average agriculture in the region which is 74 kg N per ha. Also agricultural production on these BERAS farms is rather extensive compared with the average production in the country as a whole with only15 kg N per ha in BERAS agricultural exports compared with the average production of 67 kg N per ha. As is the case for most other BERAS-farms the P balance is negative with a higher export of P in agricultural products compared to a near zero input of P.

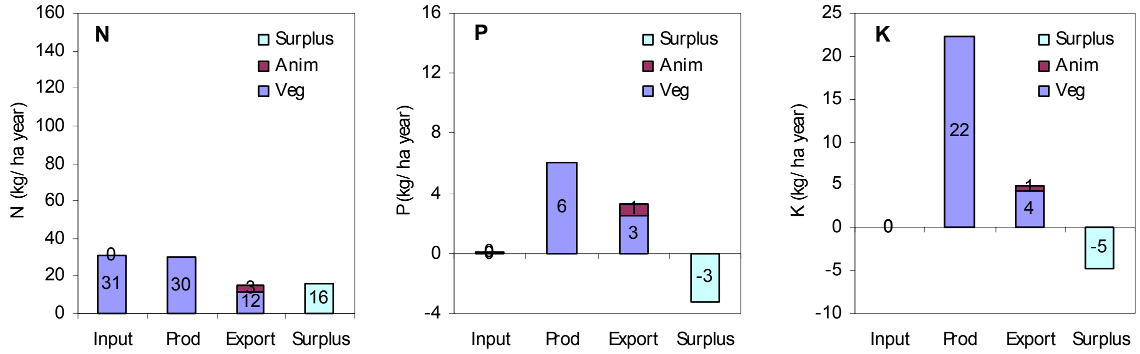

**Figure 2-21. The input, plant production, export and surplus of nitrogen (N), phosphorus (P) and potassium (K) on the two BERAS-farms in Germany 2002-2004. Animal density 0.35 au/ha.**

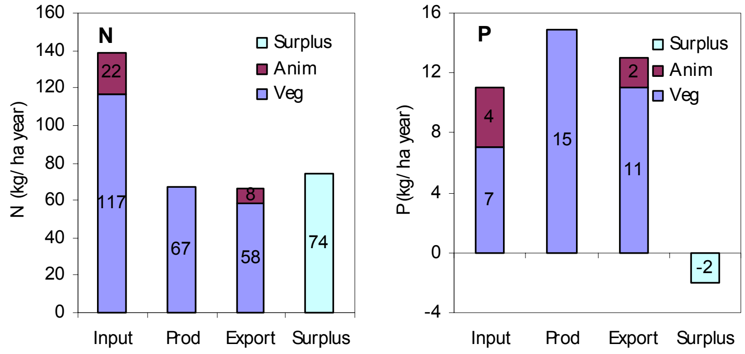

**Figure 2-22. The input, plant production, export and surplus of nitrogen (N) and phosphorus (P) in the region of Märkisch-Oderland in Germany 2002-2004. Animal density 0.4 au/ha.**

## Denmark

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*Ole Tyrsted Jørgensen, Fyn's Amt (the Funen County), Denmark.*
*Artur Granstedt, The Biodynamic Research Institute, Järna Sweden*

The Danish farms were studied according to the method described in Kristensen (2002). The nitrogen fixation is quantified from yield of pure legume crops with the coefficients from

Høgh-Jensen et al. (2003). In grass/clover and mixtures of grain/peas the fixation was estimated from soil cover of legumes, according to the method of Kristensen et al. (1995) and Kristensen et al. (2005b). The field yield of the farms was measured directly from sold crops and livestock uptake of home-grown feed-crops. The yields from grazed fields were calculated indirectly from animal production. The net storage change (storage final minus storage initial) of feed and manure was included in the figures of purchased feed/manure if it was negative and in exported crops if positive.

The BERAS-farms in Denmark are in this report represented by one vegetable farm situated on Funen, and 4 dairy farms on Jutland. The dairy farms were selected for having the lowest External Fodder Rate (EFR) among 13 organic pilot farms investigated by Nielsen and Kristensen (2005). Due to the net import of animal manure and the high feed import it was not possible to find farms fulfilling the criteria of maximum 15 % External Fodder Rate. The farms had an average of 21% ERF with a range between 33 and 15 %. This average is 16 % lower than the average of the organic pilot farms in the period of 1997-2003, see Appendix 2. The farm gate N-surplus was 87 kg N per ha (Figure 2-23) which is higher than other BERAS-farms presented. It is however 32 percent lower than the average (mainly conventional) Danish agriculture which has an average surplus of 129 kg N per ha (Figure 2-24). Compared to the organic dairy pilot farms in the period of 1997-2003 the Danish BERAS farms had 18 % lower N-surplus, see Appendix 2. However if the farm gate N-balance are recalculated to year 2002 with the average BERAS stocking rate of 0.99 au/ha (according to the definition ERA farms should have <0.75 au/ha but such farms were not possible to find in Denmark) the difference is narrowed to only 6 % lower farm gate balance on the Danish BERAS farms compared to average organic dairy pilot farms.

Forty eight percent of the area of Nørregaard's vegetable farm was unused or under low productive permanent grass (1-2 tons DM/ha/year). If the entire farm area is used for calculating the per ha nutrient surplus the N surplus is 15 % lower than if only the cultivated land is included in the balance, see Appendix 2. In Denmark only 8% of farm area is under permanent grass. The Nørregaard figures on cultivated land have been used for calculating the average.

In the period 1997-2003 the average N-surplus on organic agriculture was decreased by 14 % (Nielsen and Kristensen, 2005), due to restrictions in import of conventional feed. These restrictions were prohibited from year 2001.

On representative organic mainly crop producing farms with 0.3 au/ha, a field balance of 61 kg N/ha has been calculated (Knudsen et al. 2005 and Berntsen et al. 2004). This corresponds to a farm gate balance of about 64 kg N/ha, if 3 kg N/ha in ammonia losses in the stable and manure storage are assumed, Kristensen (2005). Of the total area under organic production in Denmark in the year 2002 54 % was used for organic dairy, 25 % for crop production and 17 % is full time and 5% part time mixed farmers (Berntsen et al. 2004). If the measured farm gate N-surplus of the dairy and crop producing farmers represents the entire Danish organic production, the average organic N-surplus can be calculated to 85 kg N/ha (106-64)/2. This is 27 % lower than the average N-surplus for Danish agriculture as a whole (Kristensen et al. 2005a).

The surplus of nitrogen in a constructed scenario of ERA agriculture on the whole of Funen, presented in Chapter 3, shows a surplus of 59 kg N/ha and, like most other BERAS-farms, this is 45 % lower than the present agriculture on Funen. This scenario shows the potential of organic production if no import is allowed and if the plant yield is at the present level of the pilot farms. However that low surplus can be difficult and expensive to achieve (Anon. 2001). All the above calculated organic balances are influenced by the assumptions about the level of nitrogen fixation. If 25 % higher/lower fixation is assumed the dairy farm balance will decrease/increase by 17 % (Knudsen et al. 2005).

The P balance is the same on all the Danish BERAS-farms. They have an average surplus of 5 kg P per ha, 3 kg P lower than the average for the whole of Danish agriculture. The BERAS farms were also 33% lower than average of Danish organic milk pilot farms in the period of 1997-2003 (Nielsen and Kristensen, 2005). See Appendix 2.

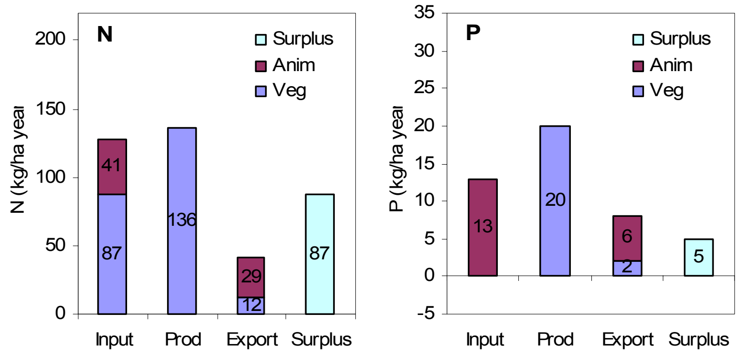

**Figure 2-23. The input, plant production, export and surplus of nitrogen (N) and phosphorus (P) on the five BERAS-farms in Denmark 2002-2003.**

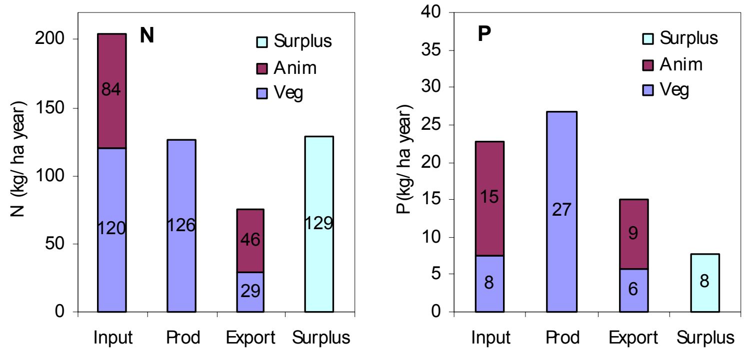

**Figure 2-24. The input, plant production, export and surplus of nitrogen (N) and phosphorus (P) in Denmark 2002.**

## *Concluding results and discussion*

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Nitrogen and phosphorus surpluses, calculated ammonia losses and based on that calculated field surplus for all BERAS-countries and the BERAS-farms are presented in Table 2-1 and Figure 2-25. The average nitrogen and phosphorus surplus in average agriculture was 56 and 11 kg per ha respectively in the BERAS project countries in 2000. On the selected BERAS-farms, the average nitrogen surplus was 32% lower, i.e. 38 kg N per ha. The calculated N field surplus was 47 % lower.

**Table 2-1. Total Load (according to HELCOM) and calculated total surplus and field surplus of N and P and ammonia losses in average agriculture and ERA agriculture represented by the BERAS project farms, showing totals and amounts per ha by country and for the total area.**

| | HELCOM | Average agriculture | BERAS agriculture |
|---|---|---|---|

|  | Arable land[1] | Loads year 2000 |  | N surplus |  | P surplus |  | NH4 loss |  | N surplus |  | P surplus |  | NH4 loss |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | *Mha* | *N t/a* | *P t/a* | *kg/ha* | *t/a* | *kg/ha* | *t/a* | *kg/ha* | *t/a* | *kg/ha* | *t/a* | *kg/ha* | *t/a* | *kg/ha* | *t/a* |
| Sweden | 2698 | 175610 | 7320 | 79 | 184000 | 3 | 8094 | 22 | 58350 | 36 | 97128 | -2 | -5396 | 21 | 57389 |
| Finland | 2387 | 146560 | 6370 | 75 | 179025 | 7 | 16709 | 14 | 32504 | 38 | 90706 | 3 | 7161 | 18 | 42913 |
| Est/Lat/Lith | 7513 | 122620 | 4070 | 19 | 141034 | 3 | 21379 | 16 | 117349 | 41 | 308033 | -1 | -3757 | 12 | 98571 |
| Poland | 14247 | 229990 | 18760 | 57 | 812079 | 19 | 270693 | 15 | 216825 | 32 | 455904 | -2 | -28494 | 16 | 233309 |
| Germany | 2051 | 31510 | 1880 | 74 | 151774 | -2 | -4102 | 9 | 18893 | 16 | 32816 | -3 | -6153 | 6 | 12723 |
| Denmark | 2077 | 62240 | 1180 | 129 | 267933 | 8 | 16616 | 54 | 112298 | 87 | 180699 | 5 | 9347 | 49 | 102687 |
| Total | 30973 | 768530 | 39580 | 56 | 1735845 | 11 | 329389 | 18 | 556219 | 38 | 1165286 | -1 | -27292 | 18 | 547592 |
| Field surplus |  |  |  | 38 | 1179626 | 11 | 329389 |  |  | 20 | 617694 | -1 | -27292 |  |  |

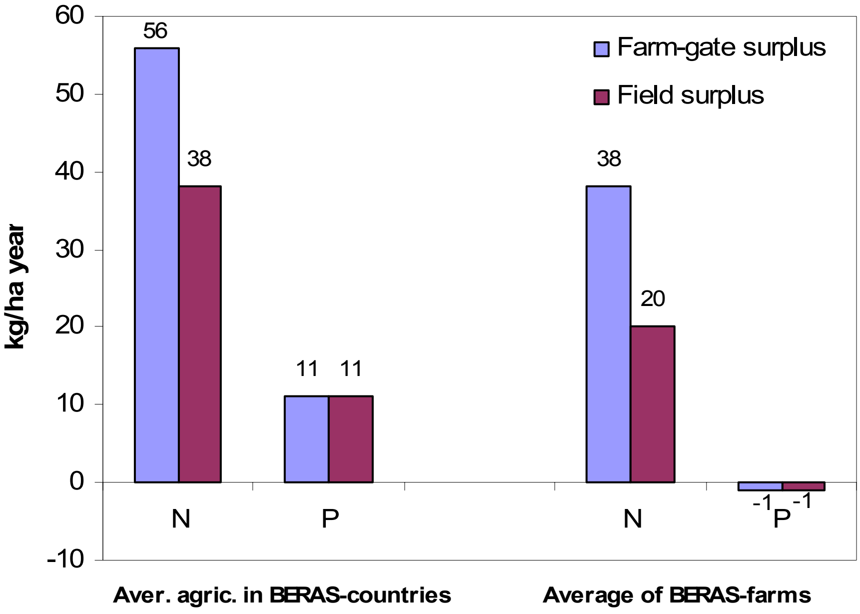

**Figure 2-25. The average nutrient farm-gate and field balance in the average agriculture of the countries in the BERAS project and on the BERAS-farms. N - nitrogen, P - phosphorus.**

Average nitrogen fixation for all BERAS-farms (in all BERAS-countries) is estimated at 42 kg per ha and year. The calculation programme STANK (Jordbruksverket, 1998) was used for this estimation and collected input data of yield and clover percent in clover/grass leys on the farms were used. These input data can be over or under estimated. If this is an underestimation and nitrogen fixation is 20 % higher then the calculated field surplus would be 22 % higher. If, on the other hand, it is an over-estimation and nitrogen fixation is actually 20 % lower then the field surplus would be 23 % lower.

Based on the results presented in Table 2-1 and Figure 2-25, different scenarios have been developed. In one fully realistic scenario Poland and the Baltic countries (Estonia, Latvia and Lithuania) change their agriculture so it is like Sweden's today. Another scenario assumes the conversion of agriculture in the whole Baltic Sea drainage area to ERA-type agriculture (Figure 2-26). In the latter it is assumed that nutrient surpluses etc. in the three Baltic countries are similar to the Swedish ERA farms.

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[1] land in the Baltic Sea drainage area only

The first scenario would result in a 58 % increase of the nitrogen field surplus and a corresponding increase in the load to the Baltic Sea. Most likely there would also be a similar increase of the phosphorus load. The consequences of the second scenario where all agriculture in the Baltic drainage area is converted to ERA would be very different. It would result in a decrease of the nitrogen surplus with 47 %. In this scenario the phosphorus surplus would be zero and would thus result in a significant decrease of the phosphorus load to the Baltic Sea. This scenario should also have several other both environmental consequences like increased biological diversity and diversified landscape as well as socio-economical consequences which will be discussed further in the final concluding interdisciplinary BERAS report which will take include aspects based on the results from the economical and sociological BERAS-studies.

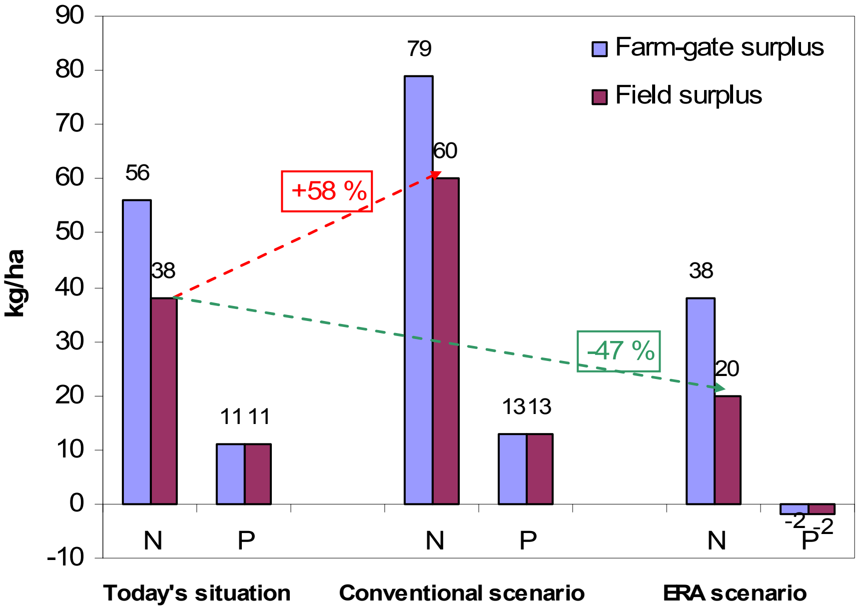

**Figure 2-26. Surplus of nitrogen and phosphorus in farm-gate and field balances calculated for three alternatives: The Today's agriculture situation; a scenario where agriculture in Poland and the Baltic countries is converted to conventional agriculture similar to agriculture in Sweden (Conventional scenario); all agriculture in the Baltic Sea drainage area is converted to Ecological Recycling Agriculture (ERA scenario).**

## *Evaluation of nitrogen utilization by means of the concept of primary nutrient efficiency*

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This work is also reported as Seuri, P. & Kahiluoto, H. (2005) "Evaluation of nitrogen utilization by means of the concept of primary production balance" in Köpke et al. (2005) but is here somewhat revised. Nutrient balances (farm-gate balance, surface balance[2] and cattle balance) only indicate an absolute load of nutrients as a difference between input nutrients and output nutrients (kg or kg/ha). Basically they do not say anything about the efficiency of nutrient utilization.

It is also possible to calculate a ratio between output and input. This type of ratio can be used as a measure of nutrient utilization efficiency. As long as the system is simple enough, i.e. a farm without livestock and with no recycling of nutrients, the output/input ratio indicates the

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[2] also referred to as field balance in this publication.

efficiency of nutrient utilization. However, as soon as a system involves recycled nutrients, the output/input ratio is difficult to interpret (Myrbeck 1999).

From an ecological point of view there is only one production process in the agricultural system, i.e. crop production = primary production. Primary production can either be used directly as human food or fed to animals. Nutrient load and nutrient utilization, i.e. efficiency of nutrient utilization, are two separate dimensions. If only crops are produced, the nutrient load is less than if an equal amount (in kg nitrogen) of animal products is produced but the efficiency to utilize nutrients is equal. This is because more crop products are needed to produce an equal amount of animal products. This can be explained by two examples:
A) If 1 kg nitrogen in crop products are produced and used as human food, there are some losses, let's say 0.4 kg nitrogen. These losses are also the total load.
B) If 1 kg nitrogen in animal products are produced and used as human food there must first be produced some crops for fodder. Let's say we are able to produce1 kg nitrogen in animal products by 4 kg nitrogen in crops (fodder) (= cattle efficiency = 25%). If each kg nitrogen in fodder is produced with same efficiency than in case A, this means that total losses are 4 x 0,4 kg nitrogen = 1,6 kg nitrogen. The efficiency to utilize nitrogen on the field has been equal in both cases A and B (60 %) and equal amount of human food has been produced (1 kg nitrogen), but the total load in case A is 0,4 kg nitrogen and in case B 1,6 kg.

In order to reduce the nutrient load there are two possibilities: either produce less or improve the efficiency of nutrient utilization. Since the amount of primary production is highly dependent on the priorities in the human diet, it can be taken as a given constant. According to this assumption, the harvested yield (Y) to external nutrient input (= primary nutrients, P) ratio alone indicates the nutrient utilization in any system. The concept of primary nutrient efficiency (PNE) is based on this fact (Seuri 2002) but now renamed. Earlier it was called primary production balance (PPB).

The aims of this study were:

- To introduce a new method, primary nutrient efficiency, for the evaluation of nutrient utilization
- To demonstrate and find the key factors to reach a high utilization rate of nutrients

## Material and methods

A deeper analysis was made of nitrogen utilization on nine organic farms in eastern Finland, referred to as J-BERAS-farms earlier in this chapter and in Appendix 2. Data was collected in 2004 by personally interviewing farmers. An overall picture was drawn of how the farms were functioning and, to ensure the validity of data, the results were discussed personally with each farmer. The estimations of harvested yield (dry matter & nitrogen) were adjusted with the number of animals and total animal production. The nitrogen contents of all organic materials within the system (crops, fodder, bedding materials, seeds, animal products, and purchased manure) were estimated by means of standard figures, unless measured values were available. Atmospheric deposition, 5 kg nitrogen/ha, was included as an input.

All the main nutrient flows were identified. However, because of the steady-state assumption (i.e. balanced systems, no change in reserve nutrients in soil) and estimation of biologically fixed nitrogen the results may include some error.

Biological nitrogen fixation (BNF) was estimated based on harvested legume yield: the assumption was 50 kg nitrogen per 1000 kg harvested dry matter of legume. That means that roughly 70 % of the total nitrogen content in the legume biomass originated from BNF. This assumption was derived from the Swedish STANK model (STANK 1998), the Danish model by Kristensen et al. (1995) and the Finnish model by Väisänen (2000). On all farms the most important legume was red clover. However, some white clover and alsike clover were grown in perennial ley mixtures as well. Besides peas, which was the most important annual legume crop, some annual vetch was grown.

The farm-gate efficiency, surface efficiency and primary nutrient efficiency (PNE) were calculated for each individual farm (Table 2-2). The primary nutrient efficiency can be calculated from the following two equations (Seuri 2002):

(I) $PNE = Y/P$

where Y = total harvested yield and P = primary nutrients (= external nutrients)

(II) $PNE = U * C$

where U = utilization rate (= surface efficiency) and C = circulation factor = $(P + S)/P$
S = secondary nutrients (= recirculated nutrients)

Equation (I) follows the definition of PNE. Equation (II) illustrates two components of PNE: utilization rate, which is equal to surface efficiency, and circulation factor, which indicates the extent of recirculated nutrients in the system. There is a major difference between farms with and without livestock. Since there are no recirculated nutrients (S) on farms without livestock, the circulation factor is always 1.0. On farms with livestock the circulation factor is always higher than 1.0.

To illustrate the difference between primary and secondary nutrients and to point out the role of recirculation in improving nutrient utilization, some simple simulations were made on two farms without livestock, farms 8 and 9. The farms produce some fodder and receive some farmyard manure (FYM) from the neighbouring farm. The initial efficiency (A) indicates utilization in a case where manure from the neighbouring farm is an external nutrient input (primary nutrient). The simulated efficiency (B) indicates the utilization in a case where all the harvested fodder yield is used on the farm for dairy cattle. It is assumed that 25 % of the nitrogen in the fodder is sold out from the farm in the form of milk and beef and 25 % is lost in the gaseous form before the manure is spread on the field. The rest of the nitrogen (50%) remains in the manure.

The average utilization rate of the primary nitrogen in the agriculture in Finland was calculated from statistics. Rough estimations and comparisons were made between the farms in this study and national average utilization rates.

## Results and discussion

| Farm | Production type | Primary N input (kg/ha) | Total N on field (kg/ha) | Harvested N yield (kg/ha) | Primary nutrient efficiency | Surface efficiency | Farm-gate efficiency | Circulation factor | N surplus (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Dairy | 60 | 92 | 69 | 1.15 | 0.75 | 0.34 | 1.53 | 40 |
| 2 | Dairy | 68 | 108 | 75 | 1.11 | 0.69 | 0.3 | 1.60 | 49 |
| 3 | Dairy | 53 | 83 | 53 | 1.00 | 0.64 | 0.3 | 1.56 | 44 |
| 4 | Beef | 69 | 113 | 84 | 1.22 | 0.74 | 0.18 | 1.64 | 60 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Beef | 65 | 113 | 73 | 1.13 | 0.65 | 0.20 | 1.74 | 53 |
| 6 | Beef (+crop) | 52 | 89 | 55 | 1.05 | 0.62 | 0.17 | 1.70 | 48 |
| 7 | Goat (+crop) | 63 | 73 | 45 | 0.72 | 0.62 | 0.30 | 1.16 | 55 |
| 8A | Crop | 87 | 87 | 49 | 0.56 | 0.56 | 0.56 | 1.0 | 39 |
| 8B | ‘Dairy’ | 63 | 87 | 49 | 0.77 | 0.56 | 0.19 | 1.39 | 51 |
| 9A | Crop | 66 | 66 | 34 | 0.51 | 0.51 | 0.51 | 1.0 | 33 |
| 9B | ‘Dairy’ (+crop) | 48 | 66 | 42 | 0.87 | 0.63 | 0.3 | 1.38 | 34 |

**Table 2-2. Comparison between primary nutrient efficiency (PNE), surface efficiency (SE) and farm-gate efficiency (FGE) of nitrogen on nine organic farms in eastern Finland. Farms 8B and 9B are simulated from 8A and 9A, respectively.**

The PNE of nitrogen fell in the range 1.0 - 1.2 on all mixed farms except for farm 7, i.e. the farms were able to harvest more nitrogen than they received as an input into the crop production from outside the farm. Both farms without livestock reached a PNE down around 0.5; the dairy farm simulation increased the PNE up to 0.8.

The surface efficiency (SE) of nitrogen fell in the range 0.6 - 0.75 on all mixed farms and by definition PNE and SE are identical (around 0.5) in a system without livestock, i.e. in any system without recirculated nutrients. The Farm Gate Efficiency (FGE) of nitrogen correlated strongly with production type, being around 0.3 on dairy farms and around 0.2 on beef farms. Analogously to PNE and SE, also FGE was identical on farms with no livestock (around 0.5). The dairy farm simulation decreased the FGE down to 0.19 on farm 8 and down to 0.3 on farm 9.

Simulation on farm 8 shows clearly the role of recirculation and the difference between PNE and SE. On farm 8, the only difference between the real farm and the simulated farm is the method of definition of the origin of input nitrogen, i.e. the initial yield harvested and the initial amount of nitrogen available in the field are exactly the same. On farm 8A, all the nitrogen in the farm yard manure (FYM) from the neighbouring farm is considered as primary nitrogen analogous to the nitrogen in artificial fertilizers or the nitrogen from BNF. This is analogous to any nitrogen input that increases the total amount of nitrogen in the system. On farm 8B, the nitrogen in the FYM from the neighbouring farm is considered as secondary nitrogen analogous to the nitrogen in FYM originating from the farm. This is analogous to any recycled nitrogen that does not increase the total amount of nitrogen in the system. However, the SE method does not identify the origin of the nutrients in the field, i.e. unlike PNE, SE remains constant on farm 8. The higher PNE value on the simulated farm 8B indicates higher efficiency of primary nitrogen utilization, thereby a lower nitrogen load potential.

On farm 9B there are some green manure fields, from where yield is harvested instead of ploughing directly. Therefore also the SE is influenced by simulation on farm 9, but otherwise it is analogous to farm 8.

In Finland (1995 - 1999), calculations of nitrogen balance in agriculture show that the annual total primary nitrogen input (artificial fertilizers, atmospheric deposition and symbiotically fixed nitrogen) is about 100 kg/ha. The total harvested nitrogen yield is about 74 kg/ha, (Lemola & Esala 2004). Thus, the PNE in agriculture averages 74 kg/ha / 100 kg/ha = 0.74, indicating a serious lack of nutrient re-cycling. However, there is huge potential to recycle nutrients in agriculture, because 80 % of the total crop yield is used as animal fodder.

In this study, all the livestock farms exceeded the value 0.74. They ranged from 0.8 - 1.2, with an average around 1.0. The high PNE for nitrogen was due not only to recycling but also to biological nitrogen fixation. The main source of primary nitrogen input was symbiotic fixed nitrogen by legumes. The utilization rate of nitrogen by legumes is clearly higher than for any other source of nitrogen into a system. In most cases about the same amount of nitrogen was harvested as was symbiotically fixed, i.e. the utilization rate is approximately 100%.

In addition, the balance between livestock and field area (fodder production) was of major importance in reaching a high PNE. Whenever the livestock density was increased by means of purchased fodder, the utilization of farmyard manure was poor and resulted in lower PNE (farms 3, 6 and 7). Self-sufficient fodder production was the optimum. The farms with high PNE had also a slightly higher yield level than farms with lower PNE.

On the other hand, the two organic farms without livestock indicated that without recirculation an organic system cannot utilize nitrogen very efficiently. On these farms the primary source of nitrogen consisted of legumes, but because the legume crop was partly used as green manure, there were heavy losses of nitrogen resulting in a lower total PNE.

## Conclusions

It was fairly easy to calculate the primary nutrient efficiency (PNE) for each of the nine farms included in this study. The estimation of biological nitrogen fixation and harvested nitrogen yield are, however, obvious sources of error. The assumption of steady state is not necessarily valid in all cases.

Even though crop production causes only minor nutrient load compared with animal production, it does not necessarily mean that crop farms utilize nutrients effectively. Using the PNE it is easy to compare different farms. The results of this study show clearly that livestock farms are able to reach a remarkably higher PNE compared with crop farms despite the very low farm-gate efficiency on livestock farms.

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# 3. Effects of 100 % organic production on Funen, Denmark

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## *Introduction*

Organic agriculture production has been found to lower the environmental impact compared to present conventional production. This effect is partly a result of lower stocking rates and partly because of a higher utilization of N-input (Nielsen and Kristensen, 2005). The present organic production in Denmark is mainly milk production on specialized organic dairy farms, with a high stocking rate of 1.4 Livestock Units (LSU[3]) per ha cultivated land and only 5% N-export in crop production (Kristensen et al., 2005b). Milk production uses external inputs in the form of feed, straw and animal manure. These inputs are  partly conventional straw and pig manure and partly organic feed from mainly organic crop production farms, which also have considerable external inputs in the form of manure (33% of total N-inputs, Kristensen, 2005a, 50 kg N/ha Berntsen et al., 2004). The assumption that a closer integration between animal and crop production within the same (or nearby) farm unit will contribute to a better resource utilization and a lower negative environmental impact has been tested in this BERAS project. Such agriculture is termed ecological recycling agriculture (ERA). See chapter 2 in this publication.

This chapter looks at the consequences of changing the present Danish agriculture to organic production that in principle follows the ERA concept. In order to quantify this, a modelling approach has been developed. The aim has been to analyse the possible impact of organic production on the nutrient loads to the Baltic Sea compared to the present loads from conventional agriculture. The Funen County has been chosen because it is representative of the average stocking rate of 0.8 LSU/ha of Danish agricultural production that lies in the drainage area of the Baltic Sea. Also considerable previous work has been done on the Funen county agriculture giving data that makes it possible to quantify the present environmental impact on the Baltic Sea (Anon., 2003 and Terlikowska et al., 2000).

## *Methods*

In Denmark data from all farms – including Funen - are available in 3 government databases:
The "*Fertilizer Accounts*", with data of fertilizer use and standard animal manure production, distribution and import/export;
The "*Land use Register*" (General Agricultural Register), with data on area (ha) of production of main crops (winter wheat, spring barley, grass/clover etc.);
The "*Animal Register*" (Central Husbandry Register), with data on the number of animals by animal type (dairy cows, heifers, steers, sows, piglets, slaughter pigs, hens, chicken etc.).

In **F**arm **A**ccounts **D**ata **N**etwork (FADN)-data (Anon., 2005a and Brendstrup, 2005) annual economic data from 2300 representative Danish farms is available. From these FADN-data *"Representative Accounts"* organic animal production and cash crop yields have been deducted.

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[3] 1 LSU = 0.85 Frisian dairy cow or 0.34 heifer/steer or 36 slaughter pigs = 100 kg N from stored manure. For further details see Appendix 1.

Information about cash crop yields from conventional agriculture on Funen has been extracted from "*Danish Statistics*"[4]. Only average yield per crop for the whole of Funen County is available. No separate data is available for organic production and yields for Funen. For this reason organic grain yield has been calculated from the national FADN–data's "*Representative Accounts*". Based on FADN-data from 4 years the average annual yield has been calculated for organic farms as a proportion of the yield from conventional farms. The average organic cash crop yield was calculated from the average conventional crop yield on Funen (Anon., 2005b), reduced with an average yield reduction factor, which is 71 % on organic dairy farms (Kristensen, 2005b) and 54 % on organic arable farms on loamy soils (Kristensen, 2005a). The yield has been calculated as the mean grain yield achieved in 236 and 1104 organic and conventional farms in the period of 1999-2002, registered on representative FADN farms on loamy soils in Denmark (Anon., 2005a). For calculating average total yields for each farm the average N-yield of small area crops (seed-crops, lucerne and vegetables) has been assumed to be the same average N-yield as grain crops.

For calculating the farm gate N- and P-balance the use of feed and nitrogen for feeding and animal products has been calculated from the FADN-data (See Kristensen and Kristensen (2004) for a brief description and Dalgaard et al., (2004) for details). The calculations assume that standard Danish feed and protein requirements are met. These are described in Poulsen and Kristensen (1998) and updated annually. For these calculations standard livestock products are calculated from the number of LSU (from "*Fertilizer Accounts*") and the animal production per LSU from (FADN-data *"Representative Accounts")*. The total feed requirements are calculated from standard feed requirements using the N-requirement found by Nielsen and Kristensen (2005): 22.1 % N-efficiency$_{\mathrm{Herd}}$ for conventional dairy herds, 20.5 % N-efficiency$_{\mathrm{Herd}}$ for organic dairy herds, 35.4 % N-efficiency$_{\mathrm{Herd}}$ for pigs, 48 % N-efficiency$_{\mathrm{Herd}}$ for hens and chickens and 30 % for other animals. The N-feed requirement is calculated as N-products$_{\mathrm{Animal}}$/N-efficiency$_{\mathrm{Herd}}$. For example a dairy cow producing 40 kg N/cow has an N-requirement of 40/0.221=181 kg N/cow/year. The feed- and protein-requirements not fulfilled from home-grown roughage and grains are imported as feed from external sources.

Farms have been grouped into specialized main farm types according to the definitions of farm types given by Larsen (2003) and in appendix of Kristensen et al. (2003). In short the dairy and pig farms have more then 90 % of their gross margin from dairy or pig production. Gross margin is defined in the FADN-data (Anon., 2005a). By definition specialized crop production farms grow sugar beets, seed crops and/or potatoes on at least 10% of the farm area and/or they have less than 0.5 LSU/ha. Organic farms have been divided into two main groups: organic dairy farms and all other organic farms. The latter includes many hobby and part times farmers. Hobby and part time farmers are also included in the data for the whole of Funen.

Nitrogen fixation is calculated directly from the average legume soil cover and the area under grass/clover. The level is based on estimates from around 50 pilot farms per year, during the period of 1989-2003. Study pilot farms are private commercial farms for intensive investigations, se methods described by Kristensen and Hermansen (2002). On organic farms field yields were published by Halberg and Kristensen (1997) and fixation by Halberg et al. (1995). The overall average fixation by the entire period 1989-2003 was estimated to 150 kg N/ha for organic and 100 kg N/ha for conventional grass/clover crops. See Kristensen et al.,

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[4] Statbank Denmark, see http://www.statistikbanken.dk/statbank5a/default.asp?w=1024

(2005b) (Appendix) and Nielsen and Kristensen (2005) for information on assumptions and levels for all crops.

Based on the above the farm gate balance has been calculated. The farm gate surpluses express the overall potential losses to the environment (Halberg et al., 1995). The surplus can be divided into aerial losses of ammonia, denitrification and soil-N changes. The N-leaching can then be calculated by difference: Surplus minus aerial losses minus/plus soil-N changes. Aerial losses of ammonia were calculated using the emission coefficients of stalls and stables mainly after Poulsen & Kristensen (1998), and updated by Hutchings et al. (2001) and Illerup et al. (2002) and the denitrification losses after Vinther & Hansen (2004) . The average weighted emissions are shown in the Appendix, Kristensen et al. (2005b).

The P-balance has been assumed to be comparable to the levels reported in the FADN data *"Representative Accounts"* and then adjusted to fit the present agriculture structure on Funen. In principle, similar to the methods used for calculating nitrogen balance (Kristensen and Kristensen, 2004).

# Results

## Agricultural production of Funen in year 2002

Table 3-1 shows the agricultural production on Funen in 2002 based on data from the 3 central registers mentioned above. The first 5 columns present data from the main groups of conventional and organic farms, which represent 66 % of the Funen agricultural area.

The average dairy farm herd size was 61 and 82 cows on conventional and organic farms respectively. The average stocking rate on conventional dairy farms was 1.43 LSU/ha and 0.78 LSU/ha on organic dairy farms. On the conventional dairy farms 86% of the farm area is included in a crop rotation regime and 12 % of this crop rotation area is grown with grass/clover. On the organic dairy farms 36% of the crop rotation area is grown with grass/clover. On both conventional and organic farms the remaining crop rotation area is grown with cereals, partly for grain and partly for whole crop silage harvested 2-3 weeks before full maturity. Maize for silage has become increasingly important, especially on conventional farms. Cereal grain yield was 6167 Scandinavian feed units (SFU[5])/ha on conventional farms and 31% lower on organic farms.

Roughage yields were assumed to be on the average level of the pilot farms, and the average yield of rotating crops was 5700 SFU/ha giving approximately 6300 kg dry matter (dm)/ha on conventional dairy farms and 21% lower on organic farms. (See appendix Kristensen et al. (2005b). The milk yield level in 2002 was 7984 kg energy corrected milk (ECM)/cow/year (Table 3-2) on conventional farms (Lauridsen, 2005) and 7118 kg on organic farms, calculated as 89 % of conventional (Kristensen, 2005b). Of the total SFU-intake by cows, 58% of the roughage was home-grown on conventional farms and 75% on organic farms. The average protein level was 18.4% of SFU intake and approximately 20% of dry matter.

Conventional pig farms have the same stocking rate as conventional dairy farms - 1.48 LSU/ha. Their crop production is like the arable crop production farms, with 73-78 % of the area grown with grain crops. On conventional crop farms 14 % of the area is used for seed,

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[5] 1 SFU is equal to the feeding value of 1 kg grain.

vegetable and other special plant products. On organic crop farms the grain is grown on only 60 % of the total cropping area.

The right hand columns of Table 3-1 present agriculture data for the whole of Funen County. Sixty percent of the total agriculture area is on sandy loam with more than 10% clay.

**Table 3-1. Farm characteristics on Funen in 2002.**

| | | Full time farmers[6] | | | | Non-dairy organic | Funen | | |
|---|---|---|---|---|---|---|---|---|---|
| | Unit | Dairy conventional | Dairy organic | Pig conv. | Crop conv. | | Sandy loam[5] | Sandy[4] | Total |
| Number of farms | | 462 | 8 | 653 | 844 | 186 | 2335 | 1388 | 6328 |
| Livestock units [1] | | | | | | | | | |
| Cattle | LSU | 47099 | 696 | 340 | 3451 | 261 | 41814 | 24434 | 66476 |
| Pig | LSU | 245 | 0 | 87856 | 9972 | 18 | 69595 | 40637 | 111446 |
| Other | LSU | 163 | 0 | 645 | 858 | 309 | 2017 | 1213 | 7758 |
| Area, including set aside & permanent grass | ha | 33262 | 895 | 59844 | 79331 | 3366 | 136980 | 74952 | 223990 |
| Stocking rate | LSU/ha | 1.43 | 0.78 | 1.48 | 0.18 | 0.17 | 0.83 | 0.88 | 0.83 |
| Area, including set aside & permanent grass | ha/farm | 71.9 | 111.9 | 91.4 | 93.1 | 18.2 | 58.6 | 53.7 | 35.3 |
| Set aside | ha/farm | 4.8 | 3.7 | 6.4 | 7.5 | 0.7 | 4.0 | 3.8 | 2.4 |
| Permanent grass | ha/farm | 5.0 | 22.4 | 0.8 | 2.1 | 3.0 | 2.0 | 2.4 | 1.3 |
| Area under plough | | | | | | | | | |
| Grass/clover | % of ha | 12 | 34 | 1 | 1 | 16 | 4 | 4 | 4 |
| Maize & whole-crops | % of ha | 29 | 15 | 0 | 1 | 3 | 5 | 6 | 5 |
| Winter cereals | % of ha | 25 | 5 | 52 | 43 | 15 | 42 | 41 | 41 |
| Spring cereals | % of ha | 24 | 26 | 26 | 30 | 45 | 30 | 30 | 31 |
| Sugar beets | % of ha | 6 | 4 | 7 | 7 | 0 | 6 | 8 | 6 |
| Rape | % of ha | 2 | 0 | 7 | 4 | 1 | 4 | 4 | 4 |
| Other | % of ha | 2 | 17 | 7 | 14 | 20 | 9 | 7 | 9 |
| Net yield | | | | | | | | | |
| Grass/clover[2] | SFU[2]/ha | 6000 | 5520 | 6000 | 6000 | 5520 | 6000 | 6000 | 6000 |
| Permanent[2] | SFU/ha | 2320 | 2018 | 2320 | 2320 | 2018 | 2320 | 2320 | 2320 |
| Maize&whole-crops[2] | SFU/ha | 8565 | 5095 | 8264 | 8805 | 4512 | 8521 | 8649 | 8557 |
| Cereals[3] | SFU/ha | 6167 | 4235[7] | 6422 | 6385 | 3202[7] | 6329 | 6166 | 6238 |
| Peas[3] | kg/ha | 3940 | | 3940 | 3940 | | 3940 | 3940 | 3940 |
| Winter rape[3] | kg/ha | 2820 | | 2820 | 2820 | | 2820 | 2820 | 2820 |
| Total | SFU/ha | 6756 | 3984 | 6625 | 6542 | 2,889 | 6444 | 6463 | 6411 |

1) 1 LSU = 0.85 Frisian dairy cow or 0.34 heifer or steer or 36 slaughter pigs from "DK Fertilizer Accounts", see http://www.pdir.dk/files/filer/topmenu/publikationer/statistik/2003/html/chapter04.htm

2) Average of pilot farms, 1989-2003, see appendix in Kristensen et al. (2005b)

3) Funen average from Danish Statistic, StatBank: http://www.statbank.dk/statbank5a/default.asp?w=1024

4) < 10 % clay.

5) > 10 % clay, normally 10-15 %.

6) Full time farmers work more than 832 standard hours/farm/year, see Larsen (2003) and Anon. (2005)

7) Organic grain yield is calculated from the average of 286 farms/year in the period 1999-2002, Anon. (2005)

In Table 3-2, the N-balance in year 2002 is calculated based on the assumption that Funen farmers have the same feed and product N- and P-turnover as the average Danish farmer. (For more information on these assumptions see Kristensen and Kristensen (2004).) The amounts for artificial fertilizer use and animal manure exchange on individual farms are taken directly from the central "*Fertilizer Account*" register. The farm gate N-efficiency$_{\text{Cash products}}$ are calculated from cash product outputs only. This means that exported animal manure is deducted from animal manure import (= net animal manure import) before calculating the efficiency. Organic dairy farms have a 9 % higher N-efficiency than conventional dairy farms.

At the bottom of Table 3-2 the calculated average N-losses are presented. For these calculations the average losses for each farm-type are used. Also soil-N changes are calculated according to Kristensen et al. (2005b). The N-leaching is calculated as the difference between average N-losses – soil-N changes and shown at the bottom of the table. In total the N-leaching from Funen is 63 kg /ha. This is only 1 kg N/ha lower than the independent calculation made by Schrøder (2004). As found previously the N-leaching calculated as the difference is in good agreement with calculations based on direct modelling of N-leaching (Kristensen et al. (2005). The conventional dairy farms have the highest N-surplus and the highest leaching – 91 kg N/ha. Organic dairy farms have the lowest nitrate leaching – 27 kg N/ha. The pig farms have the highest ammonia volatilisation. The farm gate N-efficiency$_{\text{Cash Products}}$ is calculated with only cash products as outputs (output - animal manure sold), and input as net animal manure input (input - animal manure sold). The table shows the highest N-efficiency for conventional crop farms, and lowest N-efficiency for conventional dairy farms.

**Table 3-2. Farm-gate balances of N on Funen in 2002.**

| | | Full time farmers[6] | | | | Non-dairy organic | Funen | | |
|---|---|---|---|---|---|---|---|---|---|
| | Units | Dairy conventional | Dairy organic | Pig conv. | Crop conventional | | Sandy loam[5] | Sandy[4] | Total |
| Farm characteristics | LSU | 47507 | 696 | 88841 | 14281 | 588 | 113426 | 66285 | 185680 |
| | kg ECM/cow/year | 7984 | | | | | | | |
| | Piglets/sow/year | | | 21.5 | | | | | |
| Farm gate balance | | | | | | | | | |
| **Inputs** | | | | | | | | | |
| Artificial fertiliser | kg N/ha | 59 | 0 | 67 | 104 | 6 | 84 | 77 | 82 |
| Animal manure | kg N/ha | 14 | 29 | 15 | 22 | 43 | 17 | 21 | 18 |
| Net feed import | kg N/ha | 137 | 47 | 156 | 21 | 11 | 81 | 94 | 85 |
| Fixation | kg N/ha | 12 | 52 | 2 | 3 | 28 | 5 | 6 | 5 |
| Deposition | kg N/ha | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| *Total inputs* | kg N/ha | *240* | *145* | *258* | *169* | *106* | *206* | *215* | *209* |
| **Outputs** | | | | | | | | | |
| Milk | kg N/ha | -49 | -26 | 0 | -1 | -2 | -10 | -11 | -10 |
| Meat, cattle | kg N/ha | 0 | 0 | 0 | -1 | -4 | -1 | -1 | -2 |
| Meat, pigs | kg N/ha | -1 | 0 | -76 | -8 | 0 | -27 | -29 | -26 |
| Animal manure | kg N/ha | -16 | -7 | -37 | -2 | -3 | -18 | -19 | -18 |
| Grain export | kg N/ha | -17 | -12 | -15 | -61 | -20 | -38 | -36 | -38 |
| Vegetative products | kg N/ha | -7 | -12 | -15 | -15 | -15 | -13 | -15 | -13 |
| *Total outputs* | kg N/ha | *-91* | *-57* | *-143* | *-88* | *-45* | *-105* | *-110* | *-107* |
| **Balance** | kg N/ha | **149** | **88** | **115** | **80** | **61** | **100** | **105** | **102** |
| **N-efficiency$_{\text{Cash Products}}$**[7] | % | **33** | **36** | **48** | **52** | **40** | **47** | **47** | **47** |
| Ammonia losses | % of N-surplus | 17 | 16 | 25 | 21 | 9 | 20 | 19 | 19 |
| Ammonia losses | kg N/ha | 25 | 14 | 29 | 17 | 6 | 20 | 20 | 20 |
| Denitrification | % of N-surplus | 18 | 26 | 14 | 18 | 27 | 21 | 9 | 16 |
| Denitrification | kg N/ha | 27 | 23 | 16 | 14 | 17 | 21 | 9 | 17 |
| Nitrate leaching & soil-N change | kg N/ha | 97 | 51 | 70 | 49 | 39 | 59 | 76 | 66 |
| Soil-N change[8] (- breakdown + built up) | kg N/ha | 6 | 24 | 1 | -2 | -7 | 3 | 4 | 3 |
| Nitrate leaching | kg N/ha | 91 | 27 | 70 | 51 | 46 | 56 | 72 | 63 |

[4] < 10 % clay.

[5] > 10 % clay, normally 10-15 %.

6) Full time farmers work more than 832 standard hours/farm/year, see Larsen (2003) and Anon. (2005)

7) N-efficiency$_{\text{Cash Products}}$ = (total outputs-output of animal manure)/ (total inputs-output of animal manure)
Dairy conventional = 32% = (88-16)*100/ (237-16).

8) Soil-N changes are calculated with C-tool, see www.agrsci.dk/c-tool/, (in Danish), see http://130.226.173.223/farmn for the Soil-N model included in the farm budgeting tool Farm-N. One day login: gst/guest

The P-balance calculations presented in Table 3-3 show a 12 kg P-surplus/ha, which is 40% higher than Schrøder (2004) and Nielsen et al. (2004). Due to feed minerals, pig farms have the highest P-turnover, and, together with conventional dairy farms the highest surplus. Efficiency was highest on organic non-dairy farms and second highest on conventional crop farms.

**Table 3-3. Farm-gate balances of P on Funen in 2002.**

| | | Full time farmers 1) | | | | Non-dairy organic | Total Funen |
|---|---|---|---|---|---|---|---|
| | Units | Dairy conventional | Dairy organic | Pig conventional | Arable conventional | | |
| **Inputs** | | | | | | | |
| Soy feed | kg P/ha | 9 | 2 | 10 | 1 | 1 | 5 |
| Grain | kg P/ha | 5 | 3 | 8 | 0 | 1 | 5 |
| Feed minerals | kg P/ha | 3 | 1 | 23 | 2 | 2 | 8 |
| Artificial fertiliser | kg P/ha | 13 | 0 | 5 | 11 | 0 | 9 |
| Animal manure | kg P/ha | 4 | 8 | 4 | 6 | 13 | 5 |
| Total inputs | kg P/ha | **34** | **14** | **50** | **20** | **17** | **32** |
| **Outputs** | | | | | | | |
| Vegetative products | kg P/ha | -2 | 0 | -7 | -11 | -4 | -8 |
| Meat | kg P/ha | -2 | -1 | -14 | -1 | -4 | -6 |
| Milk | kg P/ha | -8 | -5 | 0 | 0 | -3 | -2 |
| Animal manure | kg P/ha | -3 | -1 | -10 | -1 | -1 | -5 |
| Total outputs | kg P/ha | **-15** | **-8** | **-31** | **-14** | **-12** | **-20** |
| Balance | kg P/ha | **19** | **5** | **19** | **7** | **4** | **12** |
| P-efficiency$_{\text{Cash products}}$ | % | 39 | 57 | 53 | 66 | 72 | 57 |
| Feed minerals | kg P/LSU | 2 | 1 | 16 | 10 | 5 | 8 |
| Balance | kg P/LSU | 11 | 2 | 14 | 29 | 34 | 13 |

1) Full time farmers work more than 832 standard hours/farm/year, see Larsen (2003) and Anon. (2005)

## Modelled 100% organic agricultural production and emissions

The assumptions for making Funen 100% organic are presented in Table 3-4. They are presented in detail in Hermansen (1998), Alrøe & Kristensen (2001), Anon. (1999) and Anon. (2001). In order to illustrate the maximum benefit of organic production the scenario of 100% organic production with no external import has been calculated.

In short the main assumptions made are:

- The same farm area as the present situation is maintained and cattle, human and pig products are produced with the same crop rotation in order to maintain grain production at the present level on organic cattle farms. For this reason all farms produce both cattle and pig products.
- 40% of the area is used for production of grass/clover in order to keep up the soil fertility at the minimum level of actual organic dairy farms with a low stocking rate. At lower soil fertility the grain yield becomes unstable and is sometimes low due to low N-level and

infestation with weeds, especially root weeds. 12% of the area is used for maize and whole crop barley for silage and 14% feed grain for cattle.

- The dairy production is based on 84% roughage feed from grass/clover and 16% grain feed, see Table 3-4.
- 12% of the farm area is used for grain and vegetables for human consumption.
- The rest of the area in crop rotation (14%) is used for organic pig production. 9% of the total area is used for rape and peas in order to produce a balanced feed ration suitable for pigs.
- The organic yields are assumed to be the average from organic pilot farms studies, mainly after Halberg and Kristensen (1997).

**Table 3-4. Farm characteristics on Funen in 2002 for the existing conventional agriculture and for a 100% organic scenario.**

| | unit | Funen 2002 (conventional) | Scenario 100% organic | % of conventional |
|---|---|---|---|---|
| Number of farms | | 6,328 | | |
| Area, including set aside & permanent grass | ha | 223,376 | 223,376 | |
| Area, including set aside & permanent grass | ha/farm | 35.3 | 35.3 | |
| Set aside | ha/farm | 2.4 | 0 | |
| Permanent grass | ha/farm | 1.3 | 1.3 | |
| Cultivated area for different crops | | | | |
| Grass/clover | % of ha | 4 | 40 | |
| Conventional maize or organic whole silage crop | % of ha | 5 | 12 | |
| Winter cereals | % of ha | 41 | 40 | |
| Spring cereals | % of ha | 31 | | |
| Sugar beets | % of ha | 6 | 0 | |
| Rape | % of ha | 4 | 3.2 | |
| Other (peas in organic scenario) | % of ha | 9 | 5.2 | |
| Net yields assumed | | | | |
| Grass/clover | SFU/ha | 6 000 | 5 520 | 92 |
| Permanent | SFU/ha | 2 320 | 2 018 | 87 |
| Conventional maize & organic silage crop | SFU/ha | 8 557 | 3 000 | 35 |
| Undersown grass/clover | SFU/ha | incl. G/C | 400 | |
| Cereals | SFU/ha | 6 238 | 3 400 | 55 |
| Peas | kg/ha | 3 940 | 3 128 | 79 |
| Winter rape seed | kg/ha | 2 820 | 1 500 | 53 |
| Total | SFU/ha | 6 311 | 3 741 | 59 |

Table 3-5, the production consequences of the farm characteristics assumptions in Table 3-4 are shown. The main results found are:

- With high roughage uptake the organic milk production per dairy cow is 25% lower compared to present level.
- In order to use the fodder from 40% area grown with grass/clover the cattle herd has been increased by 40% cattle livestock units.
- Of the entire area 65% is used for cattle production, leaving 23% of the area for organic pig feed production and 12% for producing crops for human consumption.
- The pig feed includes 10% roughage and 60% grain. With this feed around 28% of the present pig production on Funen can be maintained.

**Table 3-5. Production characteristics for Scenario Funen 100 % organic with no import.**

| | unit | assumed value | % of conventional |
|---|---|---|---|

|  |  |  |  |  |
|---|---|---|---|---|
| Feed and area use for cattle |  |  |  |  |
| Grass/clover & whole crop silage | SFU/MPU[6] | 6 975 |  |  |
| Cereals | SFU/MPU | 1 302 |  |  |
| No of cattle in herds | MPU | 70 700 |  |  |
| No of cattle in herds | LSU | 108 891 | 140 |  |
| Cereals for cattle | SFU | 92 050 773 |  |  |
| Grass/clover, whole crop & permanent grass | ha | 117 155 | 52.3 | of Funen area |
| Area use for cattle production | ha | 144 229 | 64.4 | of Funen area |
| Livestock density on cattle farms on Funen | LSU/ha | 0.75 |  |  |
| Feed and area use for pigs |  |  |  |  |
| Grass/clover & whole crop silage | SFU/PU [7] | 600 |  |  |
| Cereals | SFU/PU | 3 971 |  |  |
| Peas | SFU/PU | 1 346 |  |  |
| Rape-cake | SFU/PU | 382 |  |  |
| Cereals for pigs etc. | ha | 31 868 | 14.2 | of Funen area |
| Cereals for pigs etc. | SFU | 108 350 864 |  |  |
| No of pigs | PU | 27 286 |  |  |
| No of pigs | LSU | 32 197 | 28 |  |
| Grass/clover & whole crop silage | ha | 2 966 | 1 | of Funen area |
| Peas | ha | 10 802 | 5 | of Funen area |
| Rape seed cakes | ha | 6 717 | 3 | of Funen area |
| Area use for pigs | ha | 52 353 | 23 | of Funen area |
| Livestock density of pig area on cattle farms | LSU/ha | 0.61 |  |  |
| Manure production |  |  |  |  |
| N-efficiency, cattle herd | % | 15.7 | 76 |  |
| N-production, cattle | kg N/ha | 109 |  |  |
| N-production, cattle on grass | kg N/ha | 38 |  |  |
| N-production, cattle in stable | kg N/ha | 72 |  |  |
| N-efficiency, pig herd | % |  |  |  |
| N-production, pigs | kg N/ha | 36% | 100 |  |

In Table 3-6, the farm gate balances and emissions are calculated assuming the same coefficients of emissions as in existing agriculture. The main findings are:

- The milk production is reduced by approximately 25% per cow and around 15% for Funen County as a whole.
- All male cattle were raised for meat and the beef production is doubled compared to present situation.
- The fertilizer and feed import is zero.
- The nitrogen fixation input is increased. This is mainly from the 40% grass/clover area with an N-fixation assumed to be 150 kg/ha.
- The total inputs from nitrogen fixation and deposition are reduced to 40% of the present level. This increases to 50 % if sold animal manure is deducted from the animal manure import.

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[6] MPU (milk producing unit) =1 Frisian dairy cow + 1.03 Frisian heifer + 1 steer

[7] 1 PU (pig unit) = 1 year old sow + 18,7 fattening pigs

- Pig production is reduced to 20% of the present level. This is mainly because of a decrease in the number of pigs but also partly because of lower productivity - 19 slaughter pigs per sow compared to the present 22.
- The farm gate balance is reduced by 42%, bringing the farm gate N-surplus down to 59 kg/ha.
- Using the same coefficient of emissions and soil-N changes the surplus is 37 kg N-leaching per ha. This is about a 41% reduction compared to the situation in the year 2002.
- With no external P-inputs the P-balance is about minus 6 kg/ha.

**Table 3-6. Farm gate N-balances of conventional agriculture on Funen in 2002 and a 100% organic agriculture scenario.**

| | unit | Funen 2002 (conventional) | Scenario 100% organic | % of conventional |
|---|---|---|---|---|
| **Farm characteristics** | LSU | 185 680 | 141 088 | 76 |
| | LSU/ha | 0.90 | 0.63 | 70 |
| | kg ECM/cow | 7 984 | 5540 | 69 |
| | piglets/sow | 21.5 | 18.7 | 87 |
| **Farm gate balance** | | | | |
| **Inputs** | | | | |
| Artificial fertilizer | kg N/ha | 82 | 0 | |
| Animal manure | kg N/ha | 18 | 0 | |
| Net feed import | kg N/ha | 85 | 0 | |
| Fixation | kg N/ha | 5 | 66 | |
| Deposition | kg N/ha | 18 | 18 | |
| *Total inputs* | kg N/ha | **209** | **84** | **40** |
| **Outputs** | | | | |
| Milk | kg N/ha | 10 | 9 | 90 |
| Meat, cattle | kg N/ha | 2 | 4 | 258 |
| Meat, pigs | kg N/ha | 26 | 5 | 20 |
| Animal manure | kg N/ha | 18 | 0 | |
| Grain | kg N/ha | 38 | | |
| Vegetable products | kg N/ha | 13 | 7 | 53 |
| *Total outputs* | kg N/ha | 107 | 25 | 24 |
| **Balance** | kg N/ha | **102** | **59** | **58** |
| **N-efficiency$_{\text{Cash Products}}$** | % | **47** | **30** | **65** |
| Ammonia losses | % of N-surplus | 19 | 19 | |
| Ammonia losses | kg N/ha | 20 | 11 | 55 |
| Denitrification | % of N-surplus | 16 | 14 | |
| Denitrification | kg N/ha | 17 | 8 | 47 |
| Nitrate leaching & soil-N changes | kg N/ha | 66 | 40 | 61 |
| Soil-N change[1] (- break down, + built up) | kg N/ha | 3 | 3 | |
| Nitrate leaching | kg N/ha | 63 | 37 | 59 |

1) Soil-N changes are calculated with C-tool, see www.agrsci.dk/c-tool/

## Scaling up from farm level to total N- and P-loads of the Baltic Sea from the agriculture sector

The calculated loss of nitrogen through leaching of 63 kg N/ha for Funen County 2002 represents the nitrogen leaching from the root zone (1 meter depth) assuming actual 'average' Danish farming practices. In the organic scenario this potential leaching is reduced by about 41 % to 37 kg N/ha.

To calculate the potential reduction in the land based nitrogen loads resulting from conversion to organic agriculture as modelled, the actual retention percentage from root zone for the whole watershed must be estimated. The retention percentage may be described as the percentage of nitrogen leaving the root zone but not entering the coastal waters. This must take into account both the actual percolation of water, as well as the leaching from unfarmed land. The contribution of leached nitrogen from nature and/or non-cultivated land can be roughly estimated to about 10 kg N/ha per year (Grant et al., 2004). Along the hydrological pathway from the root zone to the coastal waters a substantial part of the leached nitrogen will be retained (mainly through chemical denitrification).

In 2002 about 67 percent of the total area of Funen County was cultivated land (Anon., 2003) and the N leaching can be calculated as (0.33*10 kg N/ha) + (0.67* 63 kg N/ha) = 46 kg N/ha per.

The estimated actual diffuse N loads to the Baltic Sea from Funen County territory can be roughly estimated to about 16 kg N/ha per year in the 2001-2004 period (Fyn's Amt, 2005), giving a retention percentage of about 65 percent. This is somewhat higher than expected for Funen County. The retention, which is normally estimated to about 50 percent (Windolf, 2005), is based on the assumption of a loss of nitrogen from the root zone of farmed land of about 50 kg/ha per year (Børgesen, 2004).

Assuming that the long term retention percentage is independent of the level of nitrogen leaving the root zone, the nitrogen load to the Baltic Sea from the organic agriculture scenario can be calculated to (0.33*10 kg N/ha) + (0.67*37 kg N/ha) = 28 kg N/ha per year. This results in a diffuse nitrogen load to the Baltic Sea of about (1-0.65) * 28 = 10 kg N/ha. This is a reduction of around 39% of the N load from diffuse sources compared to the situation of Funen County in 2002.

The calculation of the nitrogen loads to the Baltic Sea must also take the nitrogen loads from point sources (wastewater facilities and industries) into consideration. The N-loads from point sources have been estimated to an average of about 370 tons N per year in the 2001-04 period (Fyn's Amt, 2005), which is about 1 kg N/ha per year. Taking this into consideration the organic scenario would reduce the nitrogen loads to the Baltic See from about 17 kg N/ha to about 11 kg N/ha. This is a reduction of 35 percent.

Phosphorus may be lost from arable land to the aquatic environment through different pathways: surface loss, brink erosion, drain-pipes run off, groundwater run off and wind and precipitation. The phosphorus loss may also be divided in two fractions with different origins: water-soluble phosphorus loss and particle-bound phosphorus loss (e.g. soil erosion, brink loss, wind, and precipitation loss).

For the period 2001 – 2004 the total phosphorus load to the Baltic Sea from Funen County has been estimated to 0.47 kg P/ha/year. Around 24 percent of this load is due to outlets from point sources (0.11 kg P/ha/year), 27 percent is background loss (0.13 kg P/ha/year) and 49 percent is from agricultural land and scattered settlements (0.23 kg P/ha/year) (Fyn's Amt 2005).

Too roughly estimate possible changes in P loads to the Baltic Sea due to changes in the farm gate balance, phosphorus loss can be divided into particle bound phosphorus loss and water soluble phosphorus loss. Due to the very large pool of particle bound phosphorus in the Danish agricultural soils the loss of particle bound phosphorus may be assumed to stay at its present level for many years to come irrespective of any changes in agricultural practices. Some long term benefits, however, may be expected but these would not be due to the introduction of organic agriculture but rather to the implementation of other changes e.g. use of narrow strips of fallow along streams in order to reduce brink erosion. It has been estimated that phosphorus loss through brink erosion (particle bound phosphorus loss) may constitute as much as about 50% of the total phosphorus loss from diffuse sources (Nielsen et al., 2004). In Funen County in 2004 it has been estimated that about 50% of the total phosphorus loss (including point source loss) is particle bound phosphorus (Brendstrup, 2005).

Any reduction of phosphorus loads to the Baltic Sea therefore must be expected to be the result of changes in the loss of water-soluble phosphorus. As no clear links between water soluble phosphorus loss and agricultural practices (e.g. supply of animal manure) have been established on the scale of catchments no exact prognosis and only rough estimates for the environmental benefit of changing the P balance from a surplus to a negative balance can be made.

Therefore, assuming that brink erosion or particle bound phosphorus loss may be as much as 50 percent of the phosphorous loss from agriculture and scattered settlements, the water soluble part of the total loss would be about 0,11 - 0,12 kg P/ha/year. Depending of the relation between the water soluble phosphorus measured in streams and the phosphorus surplus on agricultural lands (e.g. in relation to animal density), the potential reduction of phosphorus loads to the Baltic Sea due to the negative P balance in the organic scenario would be between 0.0 – 0.12 kg P/ha/year or 0 - 25 percent of the present load. In addition this will result in lakes and near coastal waters being less affected.

## *Discussion*

The conversion of Funen agriculture production from mainly conventional to 100 % organic was calculated in accordance with the principles outlined in the Danish “Bichel-work”, Anon (2001). This initiative, the “Bichel-work”, was based on a consensus among researchers within agronomy, environment and economic disciplines in Denmark. Reaching agreement on the technical assumptions gave a high degree of assurance that all aspects known in 1996 were included in the calculations.

In this study reductions of nitrogen leaching from the soil and soil-N changes of up to 50% have been calculated for 100% organic agriculture with zero N-imports to the farm. These calculations have a high degree of uncertainty. This scenario has been recalculated for Funen County in 2002. These recalculations gave a reduction of N-leaching by 41% compared to leaching from conventional agriculture during the same year. Because the N-surplus from Funen agriculture has remained constant since 1996 (Schrøder, 2004) when the Bichel study was made these results can also be compared to the level from that study.

There are several sources of uncertainty in these calculations: the plant yield levels, N-fixation input and deficits of nutrients (potassium, phosphorus and micro minerals) with no external inputs of feed or nutrients. These uncertainties are discussed in Anon. (2001) and the consequences of six different scenarios are presented there. In addition the distribution of N-surplus into pools of losses has been simplified by assuming that the level of losses is the same as in conventional agriculture. These uncertainties affect the calculations of N-leaching as they are based on the surplus minus aerial losses and soil-N changes. For this reason the calculation of N-leaching using alternative methods is recommended. Børgesen (2004) calculated the leaching in year 2002/03 to 46 and 50 kg N /ha using the models of N-less and SKEP/DAISY. Schrøder (2004) found the same value as in this study – 62 kg N/ha. However calculating the development it is important to use the same model, so the reduction on 50 % change from conventional to organic farming can have another absolute level.

With specialized organic production a better technology could be expected within weed control, use of plant residues and animal manure the organic production could improve output, aerial N-losses could be reduced, and N-fixation increased. Also a higher level of soil-N could accumulate with the increase in the grass/clover from 4 to 40% of the cropping area (Knudsen et al., 2005). All the above expected changes could reduce N-leaching further than the calculated 50%, so that level of leaching reduction is not unrealistic.

However the 100 % organic production makes dramatic changes in the agricultural production: an increase to 40 % grass/clover area equally distributed between all farms; a doubling of beef production; and a 70% reduction of pork production. The structural change from mixed milk/pig-production to mainly beef production decreased the farm gate N-efficiency (output/input) by 10% as well, see Table 3-6. The socioeconomic consequences will be dramatic as suggested in the Bichel report (Anon. 2001).

The effect on the N-loads on the Baltic Sea is calculated to 39%, a little less than the 41 % reduction in nitrate leaching in 1 m depth, because 33% non-agricultural area – with only a low leaching level of 10 kg N/ha - is included in the total loads calculation. In the organic scenario no P is imported and this gives an annual deficit of 6 kg P/ha. The P-loads to the Baltic Sea are mainly influenced by the particle bound P which has been assumed to stay constant at its present level. The P-load is calculated to only 0-25% reduction even though the surplus can be reduced from a surplus of 13 kg P/ha to negative balance of – 6 kg P/ha.

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# 4. Nitrogen and phosphorus leakage in ecological recycling agriculture

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## *Introduction*

Organic farming is often considered as one solution to reduce eutrophication of the Baltic Sea. However, the efficiency of organic agriculture in reducing nutrient leakage from primary food production to the aquatic environment is still questioned. The most crucial part of organic agriculture for reducing nutrient leakage is nutrient management in the crop rotation. Nutrient balance studies showed that ecological recycling agriculture (ERA) had lower nutrient surplus and thus, lower potential of leakage (this report and Granstedt and others, 2004). However, direct measurements of nutrient leakage in ecological agriculture are scarce. Bergström and Kirchmann, 2000 reviewed the available literature on nitrogen leakage in organic agriculture and concluded that organic agriculture seems to have lower nitrogen leaching per hectare than conventional systems but differences were small and they were sensitive for small changes in either production system. The nitrogen leakage per mass of produced crops was higher in organic agriculture. They summarized, that nitrogen leakage is more a question of nitrogen management, e.g. crops and crop rotation, than of production system. They believed that a decrease of nitrogen leakage can be achieved by optimizing the conventional system. However, Bergström and Kirchmann, 2000 did not consider differences of different organic systems. ERA is a nutrient extensive system based on an animal density adjusted to the own fodder production on each farm unit, which has a potential of low N-leakage (Granstedt and others, 2004).

In this report we quantify nitrogen and phosphorus leakage on three ERA farms in the BERAS project. The study is based on direct measurements of nitrogen and phosphorus concentration in drainage water and water flow measurements. The results are compared with calculated standard leakage as reported to the HELCOM PLC-4 report (Brandt and Ejhed, 2002, HELCOM, 2004).

## *Methods*

### Physical settings of the test fields

The test sites in Sweden are located at Skilleby farm in Järna, 50 km south of Stockholm, and on Solmarka farm, 20 km south of Kalmar (Fig. 4-1 and Figure 2-3). Both Skilleby and Solmarka farm are managed according to the biodynamic farming practice since the 1960:s and 1970:s, respectively. The five-year crop rotation consists of three years of ley followed by winter cereals and spring cereals with insown clover grass. Skilleby farm is managed by the nearby Yttereneby farm and the animal density corresponds to 0.6 au/ha. Solmarka has its own cows and cattle and an animal density of 0.7 au/ha.

The Finnish test site is located in Juva 270 km north of Helsinki (Figure 4-1 and Figure 2-3). Organic farming practices have been applied since 1985. The six year mixed crop rotation consists of one year of spring cereal and grass seeds, two years of grassland followed by winter cereal, green manure, and spring cereal. Approximately 30 t/ha cattle sludge is spread continuously on the 1st year plot which equals about 0.3 au/ha for the whole crop rotation per year. Harvested grain yields as net yields amounted to about 2 t DM/ha and grass yields to about 6 t DM/ha.

The physical characteristics of the test fields are summarized in (Table 4-1). For more background information on the three investigation farms see Seppanen, 2004 and. Granstedt and others, 2004

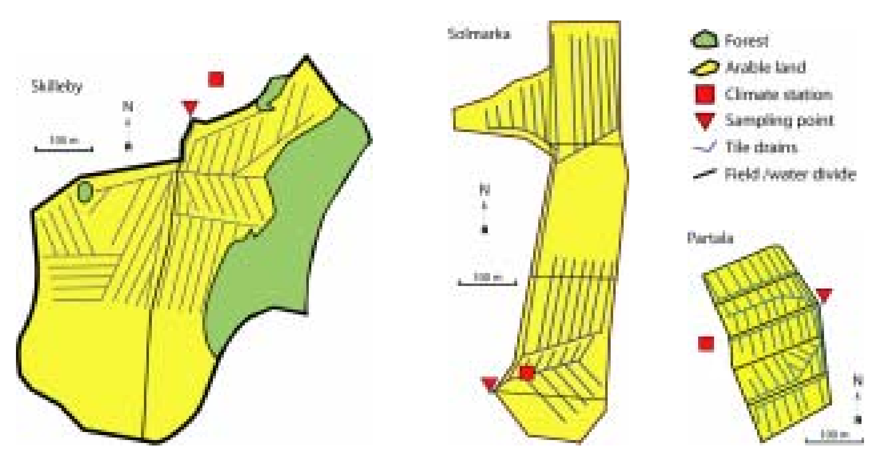

**Figure 4-1 Map of investigation fields in Skilleby (6), Solmarka (10) and Partala (14) with sampling site, drainage area and drainage system. Number in brackets according to location map (Figure 2-3). Farm characteristics are shown in Table 4-1.**

**Table 4-1. Characteristics of test fields at Skilleby, Solmarka and Partala farm.**

| | **Skilleby farm** | **Solmarka farm** | **Partala farm** |
|---|---|---|---|
| **Available data** | 030701 - 050630 | 040701 - 050630 | 01/2005-04/2005 |
| **Soil type** | Clay | Sandy loam - silty loam | Moraine |
| **Mean air temperature (°C)** | 6.6 | 7,3 | 4 1) |
| **Mean precipitation (mm/a)** | 518 | 566 | 620 2) |
| **Total drainage area (ha)** | 22.7 | 11.0 | 4.87 |

1)Juva 1997-2003 2)Mikkeli 1997-2004

## Data sampling

**Skilleby farm.** Water samples were sampled manually every second week at the outlet of a drainage pipe from the test field. The samples were analysed on N-and P-concentration in accredited laboratories. Nutrient concentration was interpolated linearly between two sampling events. Water stage was measured continuously at a V-notch thin plate weir (90°) by a pressure transducer. Stage values were transformed into discharge data by applying standard hydraulic equations (e.g. Shaw, 1993). The product of daily mean values of water discharge and interpolated nutrient concentration data yielded nutrient load from the test site. Air temperature and precipitation were measured continuously by an automatic climate station located in the test field.

**Solmarka farm.** Water samples were sampled manually every week at the outlet of a drainage pipe from the test field. The samples were analysed on N-and P-concentration according to accredited methods. Nutrient concentration was interpolated linearly between two sampling events. Water discharge was measured directly during the sampling events by means of a calibrated bucket and was interpolated linearly between sampling events. Discharge data was multiplied with measured nutrient concentration to obtain nutrient load. Air temperature and precipitation were measured continuously by an automatic climate station located in the test field.

**Partala farm.** The test field at Partala consists of five plots with five of six crops in an entire crop rotation cycle. The drainage water from the plots is directed to a V-notch weir where water stage is measured continuously with a pressure transducer. Water samples were taken manually in proportion to water flow (once a day to once a week). The water samples were analysed for both total and soluble nitrogen and phosphorus, total solids, pH and conductivity. Nutrient concentration will be interpolated linearly between two sampling events. An automatic climate station located nearby the test field measured air temperature continuously and precipitation is measured manually every day. However, measurements at Partala started in April 2005, thus, no results on nutrient leakage are available yet.

### Comparison with TRK

The obtained results at Skilleby and Solmarka on annual nutrient leakage were compared with official Swedish leakage data published as the TRK-report (Brandt and Ejhed, 2002) and reported to the Helcom pollution load compilation (HELCOM, 2004).

The TRK data was based on modelling nitrogen leakage with the SOIL-N (Johnsson and others, 1987) and HBV-N model (Arheimer and Brandt, 1998). The models simulate nitrogen leakage depending on soil type and crops. The TRK-dataset was normalized for long-term climatic fluctuations. In order to obtain comparable values of nutrient leakage, the standard values for the test fields were calculated from the standard leakage data in the TRK area 22 (Solmarka) and 60 (Skilleby) as presented in Table 4 in the TRK-report (Brandt and Ejhed, 2002). The standard nitrogen leakage was calculated for soil type and grown crops.

Standard phosphorus leakage, $P_L$, (kg km$^2$/year) was calculated according to Brandt and Ejhed, 2002 and Ulén and others, 2001 by the following equation:

$$P_L = (-0.0803 + 0.1 \cdot LD + 0.003 \cdot S + 0.0025 \cdot P_{HCl}) \cdot Q, \tag{1}$$

$$\text{where } S = (8.0 \cdot x_{clay} + 2.2 \cdot x_{silt} + 0.3 \cdot x_{sand}) \cdot \rho \cdot 0.001 \tag{2}$$

| | |
|---|---|
| $LD$ | Livestock density (livestock unit ha$^{-1}$) |
| $S$ | Soil specific area (m$^2$ m$^{-3}$ 10$^{-6}$) |
| $P_{HCl}$ | HCl extractable phosphorus (mg/100 g dry soil) |
| $\rho$ | Bulk density of soil = 1250 kg m$^{-3}$ |
| $x_{clay}$ | Clay fraction in top soil (0-30 cm), < 2 µm |
| $x_{silt}$ | Silt fraction in top soil (0-30 cm), 2 µm – 60 µm |
| $x_{sand}$ | Sand fraction in top soil (0-30 cm), 60 µm – 200 µm |
| $Q$ | Runoff (mm) |

## *Results and discussion*

### Standard leakage - TRK

Nitrogen leakage from the test fields calculated according to the method described in the TRK-report (Brandt and Ejhed, 2002) was 5.3 kg/ha year in Skilleby and 9.2 kg/ha year in Solmarka (Table 4-2 and 4-3).

**Table 4-2. Nitrogen leakage at Skilleby calculated from standard leakage defined in TRK report** (Brandt and Ejhed, 2002). **$N_{TRK}$ - standard leakage depending on soiltype, crops and climate zone according to TRK. $N_{TRK\text{-}Skilleby}$ is calculated as the product of $N_{TRK}$ and the share of the respective soiltype and crop.**

| | Area ha | Share | Soiltype | Crops | $N_{TRK}$ kg/ha year | $N_{TRK\text{-}Skilleby}$ kg/ha year |
|---|---|---|---|---|---|---|
| **2003** | 8,08 | 35% | Clay | Oats | 12 | 4.2 |
| | 9,73 | 43% | Clay | Ley | 2 | 0.9 |
| | 5,07 | 22% | | Forest | 1 | 0.2 |
| | **22.9** | | | | | **5.3** |
| **2004** | 8,08 | 35% | Clay | Ley | 2 | 0.7 |
| | 9,73 | 43% | Clay | Winterwheat | 10 | 4.3 |
| | 5,07 | 22% | | Forest | 1 | 0.2 |
| | **22.9** | | | | | **5.2** |

**Table 4-3. Nitrogen leakage at Solmarka calculated from standard leakage defined in TRK report** (Brandt and Ejhed, 2002). **$N_{TRK}$ - standard leakage depending on soiltype, crops and climate zone according to TRK. $N_{TRK\text{-}Solmarka}$ is calculated as the product of $N_{TRK}$ and the share of the respective soiltype and crop.**

| | Area ha | Share | Soiltype | Crops | $N_{TRK}$ kg/ha year | $N_{TRK\text{-}Solmarka}$ kg/ha year |
|---|---|---|---|---|---|---|
| **2004** | 0,93 | 8% | Sandy loam | Ley | 6 | 0,5 |
| | 7,47 | 68% | Silty loam | Ley | 3 | 2,0 |
| | 0,74 | 7% | Silty loam | Potatoes | 31 | 2,1 |
| | 0,74 | 7% | Silty loam | Winter wheat | 24 | 1,6 |
| | 0,37 | 3% | Silty loam | Broccoli | 27 | 0,9 |
| | 0,75 | 7% | Silty loam | Oats | 30 | 2,0 |
| | **11. 0** | | | | | **9.2** |

Standard phosphorus leakage was calculated according to equation (1) to 0.13 kg/ha year in Skilleby and to 0.14 kg/ha year in Solmarka. Input data are summarized in Table 4-4 and 4-5.

**Table 4-4. Input data from Skilleby farm to calculate phosphorus leakage according to TRK** (Brandt and Ejhed, 2002). **$P_{forest}$ is standard leakage for forest, other parameters are defined in the text.**

| Parameter | | Units | References |
|---|---|---|---|
| Area | 22.6 | ha | |
| Forest | 20% | | |
| Arable land | 80% | | |
| $LD$ | 0.6 | LU/ha | Granstedt and others, 2004 |
| $S$ | 5.93 | $10^{-6}$ m$^2$/m$^3$ | |
| $P_{HCL}$ | 55 | mg/100 g dry soil | SBFI, 2002 |
| $\rho$ | 1250 | kg/m$^3$ | Ulén and others, 2001 |
| $x_{clay}$ | 0.43 | | Granstedt, 1990 |
| $x_{silt}$ | 0.57 | | Granstedt, 1990 |
| $x_{sand}$ | 0.24 | | Granstedt, 1990 |
| $Q_{2003/04}$ | 121 | mm | |
| $Q_{2004/05}$ | 185 | mm | |
| $P_{forest}$ | 0.045 | kg/ha a | Ulén and others, 2001 |

**Table 4-5. Input data from Solmarka farm to calculate phosphorus leakage according to TRK** (Brandt and Ejhed, 2002). **All parameters are defined in the text.**

| Parameter | | Units | References |
|---|---|---|---|
| Area | 11.0 | ha | |

| | | | |
|---|---|---|---|
| $LD$ | 0.7 | LU/ha | Granstedt and others, 2004 |
| $S$ | 3.13 | $10^{-6}$ $m^2/m^3$ | |
| $P_{HCL}$ | 50 | mg/100 g dry soil | Eriksson, 1997 |
| $\rho$ | 1250 | $kg/m^3$ | Ulén and others, 2001 |
| $x_{clay}$ | 0.15 | | Bernhard, 2005 |
| $x_{silt}$ | 0.55 | | Bernhard, 2005 |
| $x_{sand}$ | 0.30 | | Bernhard, 2005 |
| $Q_{2003/04}$ | 163 | mm | |

## Climatic and hydrologic conditions

Measured precipitation is often lower than real precipitation because of losses due to evaporation from the rain gauge and due to wind effects. Results from discharge and precipitation measurements were compared with official data from the Swedish Meteorological and Hydrological Institute (SMHI). Precipitation at Skilleby was ~20% lower and runoff was ~30% lower than at the surrounding SMHI stations (Table 4-6). The difference in precipitation fits into the general precipitation pattern. However, the difference in runoff might have been caused by measuring errors e.g. ice damming in winter and during the spring flood event or leakage of water besides the gauging station. Accordingly, measured runoff was assumed to underestimate real runoff by 10%.

Differences were larger at Solmarka. Runoff at Ljungbyån was three times as large as at Solmarka whereas precipitation was similar to that at the SMHI station. The lower runoff at Solmarka is most probably an underestimation of real runoff due to the lack of continuous measurements and difficulties of measuring high discharges at the outlet of the drain pipe. Additionally, there is only one year of data available. More data is needed to draw reasonable conclusions. All results from Solmarka are based on corrected runoff, where measured runoff was multiplied by 3.3 according to the relationship between runoff at Solmarka and runoff at Ljungbyån (Table 4-6).

**Table 4-6**. **Runoff and precipitation for the period 030701-040630 at Skilleby and Solmarka and at different gauging stations from the Swedish Meteorological and Hydrological Institute (SMHI). The SMHI stations are located ~16 km from the investigation sites. Coordinates are given in local Swedish Grid (RT90, 2.5g W)**

| Location | | Runoff (mm) | Location | | Precipitation (mm) |
|---|---|---|---|---|---|
| Skilleby | 6548195 N<br>1602410 E | 110 | Skilleby | 6548195 N<br>1602410 E | 495 |
| Trosaån | 6554410 N<br>1589910 E | 165 | Gnesta | 6553550 N<br>1586690 E | 634 |
| Saxbroån | 6556690 N<br>1614570 E | 172 | Södertälje | 6563670 N<br>1603480 E | 634 |
| Solmarka | 6270230 N<br>1520380 E | 50 | Solmarka | 6270230 N<br>1520380 E | 566 |
| Ljungbyån | 6285510 N<br>1520430 E | 163 | Kalmar | 6283560 N<br>1529660 E | 587 |

The regions of Skilleby and Solmarka had similar climatic conditions during the normal period of the TRK project (Precipitation, P = 650 mm, Mean air temperature, T = 7°C) (Johnsson and Mårtensson, 2002). Compared to the investigation period in the BERAS project, the Skilleby region had similar conditions (Södertälje: P = 634 mm, T = 6.8°C). The Solmarka region, however, was dryer (Solmarka: P = 566, T = 7.3°C). Thus, the climatic influence on nutrient leakage is similar at Skilleby during both the TRK period and the BERAS investigation period which implies that differences in nutrient leakage solely depend on crops and the production system. At Solmarka, however, lower precipitation might cause lower nutrient leakage than during the TRK period.

## Measured leakage from ERA

Water discharge, nitrogen and phosphorus concentration are shown in Figure 4-2 and 4-3. Discharge follows the usual pattern with flood events in fall and during the snow melt in spring and low discharge during summer. This results in high variability of nutrient load where large amounts can be leached during some few flood events. The difference between nutrient concentration in summer 2003 and 2004 at Skilleby were due to dry conditions in 2003, where no samples were taken. However, nutrient load is not affected significantly as discharge is low during summer.

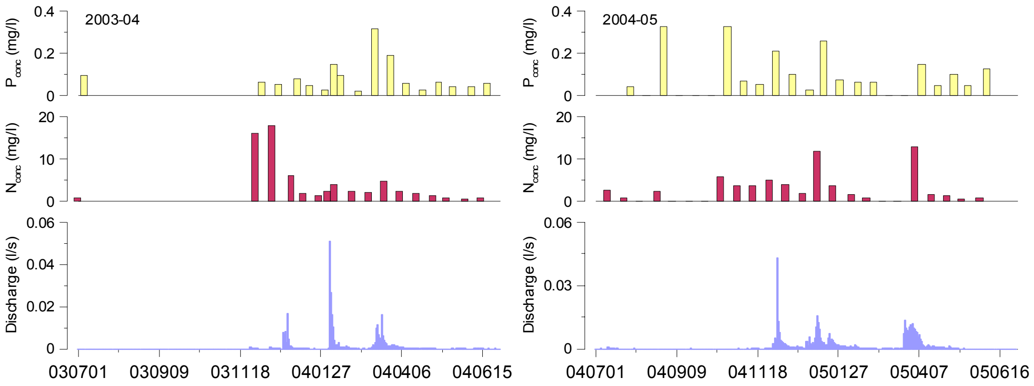

**Figure 4-2. Discharge, nitrogen and phosphorus concentration, Skilleby 2003-2005.**

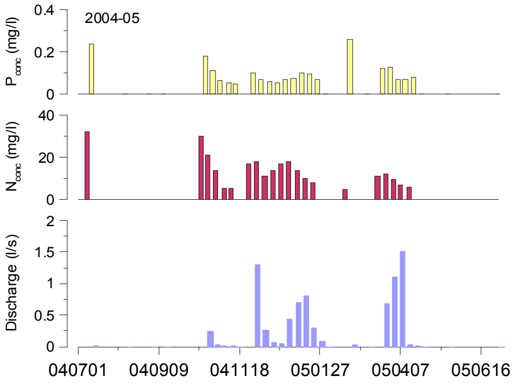

**Figure 4-3. Discharge, nitrogen and phosphorus concentration, Solmarka 2004-2005.**

Annual nutrient load is summarized in Table 4-7. In Skilleby, nitrogen leakage in 2003/04 was of the same magnitude as standard leakage for this area in the TRK project, but for 2004/05 it was the double. Nitrogen load differs significantly between the two years, whereas differences in phosphorus leakage were smaller. The large N-leakage 2004/05 most probably can be explained by releasing fixed nitrogen due to ley ploughing of half of the drainage area and spreading of manure on the same area during fall 2004. Further analyses and measurements are necessary to study whether mineralization of organically fixed nitrogen in the manure can produce enough movable nitrogen during such a short time. Even in Solmarka a large part of the field area was grassland which was ploughed in fall 2004 causing large nitrogen pulses. However, results from Solmarka are uncertain due to difficulties in discharge measurements.

**Table 4-7. Nitrogen and phosphorus leakage at Skilleby and Solmarka in comparison with the standard leakage according to the TRK-project (Brandt and Ejhed, 2002). $N_{TRK}$ was calculated according to data shown in Table 4-2 and Table 4-3. $P_{TRK}$ was calculated according to Equation 1.**

| | N<br>kg/ha year | $N_{TRK}$<br>kg/ha year | P<br>kg/ha year | $P_{TRK}$<br>kg/ha year |
|---|---|---|---|---|
| Skilleby 2003/04 | 5.7 | 5.3 | 0.18 | 0.14 |
| Skilleby 2004/05 | 11.8 | 5.2 | 0.25 | 0.22 |
| | | | | |
| Solmarka 2004/05 | 21.6 1) | 9.2 1) | 0.14 1) | 0.19 1) |

1) Results are based on corrected runoff, see text for more details.

It is always difficult to draw conclusions about general nutrient leakage from a two year data series in a five-year crop rotation system. Nevertheless, we can try to generalise our two-year-results to a larger scale. The test fields at Skilleby farm consist of two lots, on which ley was ploughed in 2004 on one lot and in 2005 on the other one. In a five-year crop rotation on two fields there are two years of ley-ploughing and three years of non-ley-ploughing. Assuming, the 2003/04 results being representative for a non-ley-ploughing season ($N_{nlp}$) and the 2004/05 results for a ley-ploughing season ($N_{lp}$), mean nitrogen leakage ($N_{mean}$) can be estimated as:

$$N_{mean} = \frac{2 \cdot N_{nlp} + 3 \cdot N_{lp}}{5} \qquad (3)$$

By applying this relationship, mean nitrogen leakage from the test fields at Skilleby farm was calculated to 8.14 kg/ha N.

The TRK results are calculated for respective area with its characteristic climate, soiltypes and livestock density. In the TRK area 60 (Skilleby) livestock density is 0.2 – 0.4 au/ha (Granstedt, 2000) whereas Skilleby farm has a livestock density of 0.6 au/ha. Nutrient surplus is strongly depending on livestock density. As shown earlier in this report (see Chapter 2) nitrogen surplus can be decreased by 40% by halving livestock density. The ERA farm produces ~40% more nitrogen leakage than farms with a 50% lower livestock density in the same area. Taking livestock density into account nitrogen leakage from ERA is of the same magnitude as the calculated standard leakage in the respective TRK area.

In the TRK area 22 (Solmarka) mean livestock density is 0.8-1 au/ha. Solmarka farm has a livestock density of 0.7 au/ha and a nitrogen leakage twice the leakage calculated in the TRK project. This is similar to the results at Skilleby during the ley-ploughing season. However, the results are limited and crop rotation is more complicated at Solmarka with several fields and crops than at Skilleby. More data is needed to draw reliable conclusions.

Phosphorus leakage from ERA is ~0.2 kg/ha year which confirms the calculated P leakage in the TRK project. The calculation of phosphorus in the TRK project depends mainly on livestock density (see Equation 1).

## Comparison with nutrient balances

Mean nitrogen surplus of all 36 BERAS farms was 36 kg/ha year. With ammonium losses of 30% respective 40%, the theoretical nitrogen leakage from the ERA farms in the project were 10 respective 7 kg N/ha year, assuming that leakage and denitrification in the soil contribute with equal parts. In addition, Skilleby farm has a livestock density of 0.6 au/ha which is similar to the mean of all BERAS farms. Mean leakage at Skilleby was calculated above to 8.1 kg/ha year. These results are, thus, in good agreement with results from the nutrient balances.

Phosphorus surplus for all BERAS farms was calculated in Chapter 2 to -1 kg/ha year. Together with a measured leakage of 0.2 kg/ha year this indicates a constant loss of phosphorus from the fields, which most probably is fed by weathering of bedrock material in the soil matrix.

## Conclusions

Within the BERAS project direct measurements of nitrogen and phosphorus leakage from fields were carried out on two ERA farms in Sweden and one in Finland. The data series which is available contains two years of measurements on Skilleby farm (Stockholm County). The data series from Solmarka farm (Kalmar County) and from the Finnish test farm in Partala were too short and are not reported here. The results from the measurements from Skilleby farm lead to the following conclusions:

- Nitrogen and phosphorus leakage from the ERA farm in Stockholm County were 8 kg N/ha year and 0.2 kg P/ha year, respectively. These results are in good agreement with the official nutrient leakage calculated in the TRK project for the same area, when taking into account differences in livestock density.
- The measured nitrogen leakage supports the results from the nutrient balances in the previous chapter of this report, where nitrogen leakage is 7-10 kg/ha year depending on the magnitude of ammoniac loses.
- The measured phosphorus leakage together with the deficit in the nutrient balances indicate a constant loss of phosphorus from the soil which most probably is fed by weathering of bedrock material in the soil matrix.

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# 5. Global warming and fossil energy use

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*Christine Wallgren, Center for Environmental Strategies Research (fms), Sweden*

Global warming and energy use are closely linked to each other since much of greenhouse gas emission is caused by burning of fossil fuels. However, emissions of methane and nitrous oxide from agriculture and industry also contribute to global warming.

The aim of this part of BERAS is to compare the environmental impacts of conventional and alternative systems in the three most important parts of the food system: production, transportation and processing. The impacts of production and processing were assessed by Olof Thomsson and that of transportation by Christine Wallgren. A final section, written by Olof Thomsson, presents the global warming impact and consumption of primary energy resources in the transportation and processing parts of the food chain.

The production assessment compares conventional and ecological recycling agriculture (ERA), defined earlier in this report. Both the results of the inventory study and the environmental impact results are reported in this section.

For the transportation and food processing assessments, the comparison concern conventional large-scale systems vs. local more small-scale systems. In the transport study, the local distribution of locally produced food in Järna was compared with available data on conventional long-distance transportation of the same product groups available in Järna shops. For the food processing industry, the same small-scale food processing plants operating in Järna were assessed and compared to large-scale food processing industries. For both components the results of direct and in-direct energy and resource use are reported separately first. Then, the combined environmental impact results are reported in a separate section at the end of the chapter.

## *Methodology*

The methodological aspects common for the three sub-studies are presented here. Specific methodological issues are described for each sub-study.

### Data inventory and impact assessment

The environmental impact assessment used in this study follows the principles of the life cycle assessment (LCA) methodology, although a complete LCA has not been made. Data concerning direct and indirect energy use and resource consumption were inventoried. This is called the life cycle inventory (LCI). Then, these data were grouped into impact categories. One emission may contribute to several impact categories. Fifteen impact categories are listed in the Nordic Guidelines for LCA (Lindfors et al. 1995). This study uses two of them; Global warming impact and Use of resources, fossil energy. Global warming impact is measured in global warming potentials (GWP) where all emissions are transformed into $CO_2$ equivalents. Of the three possible given time-spans (20, 100 and 500 years) that can be used we have chosen the 100-year perspective. Only direct impacting gases have been inventoried. These include carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$). The GWP of $CH_4$ and $N_2O$ correspond to 23 and 296 $CO_2$ equivalents respectively (IPCC, 2001). In other words, one kilo of methane gives as much global warming impact as 23 kilos of carbon dioxide and one kilo of methane is multiplied by 23 in order to get the GWP.

The inventory of energy use included two categories of energy carriers - electricity and fossil fuels. These were re-calculated as primary energy, i.e. the energy used was converted to primary energy resource equivalents. This made it possible to compare scenarios and activities using mainly electricity with those using mainly fossil fuels. This measures the consumption of energy resources in the lifecycle of the energy carriers.

Swedish electricity is produced mainly from hydropower and nuclear power but also from small parts of several other different primary energy resources. The proportion and amounts of the various primary energy resources used to produce one MJ of average Swedish electricity are shown in Table 5-1. Transmission losses in the distribution net (7 %), pre-combustion energy consumption for fuels and efficiency in e.g. hydropower and nuclear power are included in the calculations. It takes 2.35 MJ primary energy for every MJ of electricity used. The equivalent value for electricity produced in oil-fired power plants is 2.69 (Habersatter et al., 1998). For fuels, an average for different fuels has been used: 1.25 MJ primary energy per MJ fuel (calculated from Tables 16.4 and 16.9 in Habersatter et al., 1998). Fuel oil, fossil gas, petrol, and biofuels all have values ranging between 1.09 and 1.35 MJ.

**Table 5-1. Primary energy resources used to produce 1 MJ average Swedish electricity** ***(Lundgren, 1992)***

| Energy carrier | MJ primary energy resource per MJ electricity |
|---|---|
| Fossil oil | 0.064 |
| Fossil gas | 0.0093 |
| Coal | 0.040 |
| Peat | 0.0045 |
| Biofuels | 0.045 |
| Uranium[8] | 1.60 |
| Hydropower [9] | 0.588 |
| Sum | 2.35 |

## Ecological Recycling Agriculture

*Olof Thomsson, Swedish Biodynamic Research Institute, Järna Sweden*

This sub-study investigated consumption of primary energy resources and emission of gases that contribute to global warming on the 12 Swedish BERAS-farms (See Chapter 2 in this report for more details) and compared this with consumption and emissions from average Swedish agriculture. The results are presented as consumption of primary energy resources and global warming impact.

### Method

Fossil energy use and global warming impact from both direct and in-direct sources were included in the study. The direct sources included fossil vehicle fuels, heating oil, electricity, and lubricants. In-direct sources that were investigated included the production of fertilisers, fodder imported to the farm, packaging materials (primarily plastics for silage wrapping), and machinery (only primary energy consumption, not emission of global warming gases).

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[8] Calculated as MJ in uranium. 35 % efficiency is used in the conversion of MJ in uranium to MJ nuclear electricity, i.e. 35 % of the theoretical heat obtained in the fission process can be utilised as electricity.

[9] Calculated as MJ potential energy. 80 % efficiency is used in the conversion of MJ potential energy to MJ electricity

Data for the BERAS farms on energy use, imported inputs, and exported production were obtained from the farm accounts and through interviews with farmers. Comparable data for average Swedish agriculture were obtained from Sweden's statistical database (www.ssd.scb.se). Following Dalgaard *et al.* (2001), energy use was calculated using norm values for lubricants and machinery. Data from literature were used to calculate energy use and emissions in the production of the energy carriers and inputs. For the calculation of the global warming impact, literature data on direct methane emission from animals (Cederberg & Flysjö 2004, Hille 2002) and nitrous oxide emission from soil (IPCC, 2001) were used. Methane emissions from manure storage were not included. Energy use and greenhouse gas emissions for the production of the different inputs are shown in Table 5-2. Impacts from the production of pesticides were omitted as it was assumed that their impact on the specific environmental impacts under consideration was small.

**Table 5-2. Norms for the energy use in production of different agricultural inputs (with references)**

| | value | unit | reference |
|---|---|---|---|
| diesel and heating oil | 35.87 | MJ/l | Statistics Sweden (2004) (EN 16 SM 0404, page 8) |
| electricity | 3.6 | MJ/kWh | (by definition) |
| lubricants | 3.6 | MJ/l diesel | Dalgaard et al. (2001) |
| fertiliser (N28) | 12.65 | MJ/kg N | Davis & Haglund (1999) (Appendix C.1) |
| fodder (many) | 0.8-6.3 | MJ/kg | Cederberg (1998) |
| plastics (LLDPE) | 94.02 | MJ/kg | Audsley et al. (1997) |
| machinery | 12 | MJ/l diesel | Dalgaard et al. (2001) |

The calculations were performed for each BERAS-farm (not included here) and then aggregated by production type. Although all farms have more or less diversified production they were grouped according to their main production in four groups (Table 5-3). The results are presented for the four production groups of BERAS-farms, for an average of all the BERAS-farms and for average Swedish agriculture.

**Table 5-3. Farm production type groups**

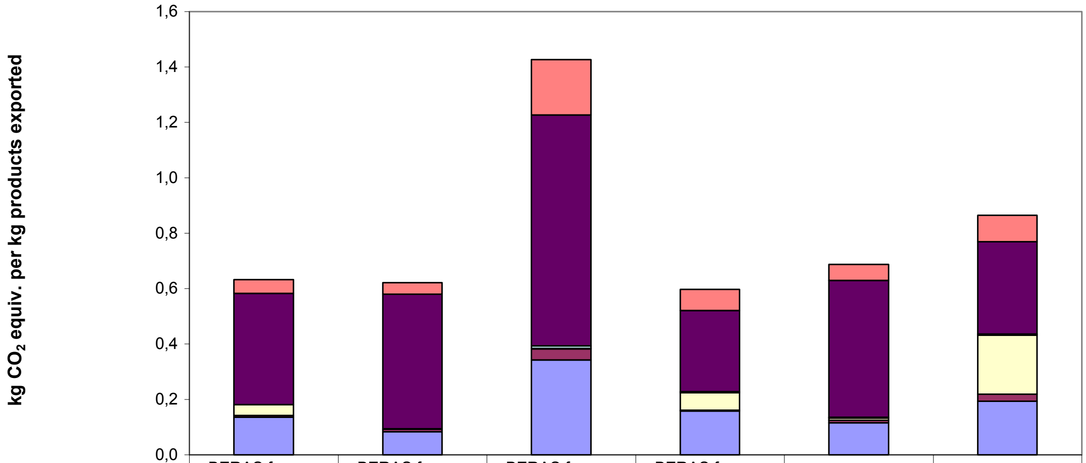
| Farm group | No farms |
|---|---|
| Mixed production with vegetables | 2 |
| Milk, beef and cereals | 6 |
| Pork, poultry, egg and cereals | 2 |
| Cereals and beef | 2 |

## Results and discussion

The global warming impact, measured in Global Warming Potentials (GWP) as $CO_2$ equivalents, is reported per kilo products exported from the farm (Figure 5-1) and per hectare (Figure 5-2). It is important to note that the per-hectare figures are calculated per hectare on the actual farms and for Sweden respectively, i.e. the foreign acreage used for producing imported fodder is not included.

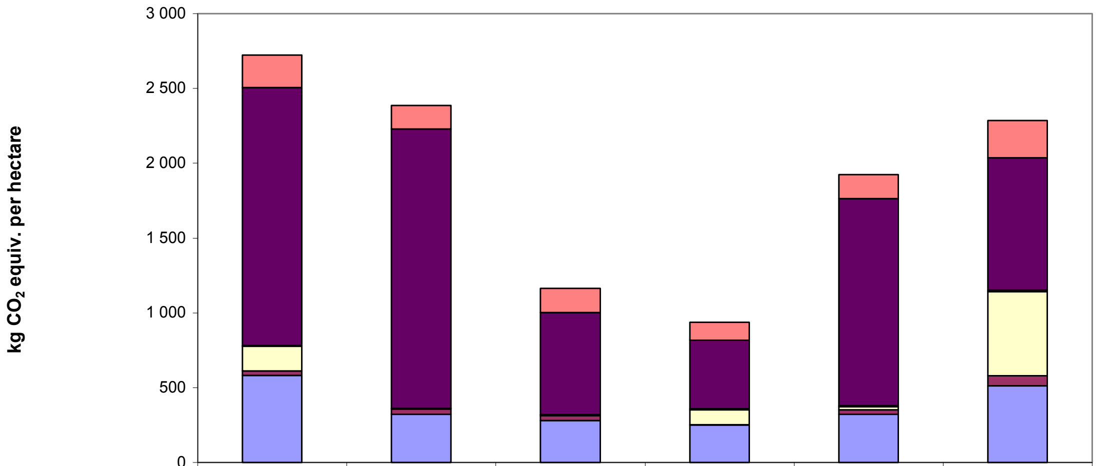
In both cases the GWP is somewhat lower for the average BERAS-farm than for the average Swedish agriculture. The main reason was the non-use of chemical fertilisers on the BERAS-farms. This resulted in both lower direct impact from fertiliser production and lower emission of nitrous oxide from soil (due to lower input of nitrogen). Lower use of fossil fuels also played a role. The large difference in electricity use (Figure 5-3) do affect the global warming impact very little since Swedish average electricity mainly is produced by hydropower and nuclear power, which have very small global warming impact.

There are two main reasons why the difference between the average BERAS-farm and the average Swedish agriculture is not greater. One is the larger share of ruminant animals on the BERAS-farms and their larger emission of methane compared to average Swedish agriculture that has a larger proportion of monogastric animals which emit very little methane. The larger share of ruminants is explained by the fact that ERA farms have more grass/clover leys than average Swedish agriculture – and the only animals that can utilise these crops are the ruminants. The second is the less intensive production per animal, making more methane emitted per kilo product compared to conventional production. The very large GWP from animals in the "Pork, poultry, egg"-group originates mainly from cattle (beef production) that are also kept on these farms. The GWP from the other factors investigated was substantially lower on the average BERAS-farm compared to average Swedish agriculture.



| | BERAS farms - mixed prod. with vegetables | BERAS farms - milk, beef and cereals | BERAS farms - pork, poultry, egg and cereals | BERAS farms - cereal and cattle prod. | BERAS farms - average | Swedish average agriculture |
|---|---|---|---|---|---|---|
| 🟥 Soil | 0,05 | 0,04 | 0,20 | 0,08 | 0,06 | 0,09 |
| 🟪 Animals | 0,40 | 0,49 | 0,83 | 0,29 | 0,49 | 0,33 |
| ⬜ Plastics | 0,00 | 0,00 | 0,01 | 0,01 | 0,00 | 0,00 |
| 🟨 Imported fertiliser/manure | 0,04 | 0,00 | 0,00 | 0,06 | 0,01 | 0,21 |
| 🟫 Imported fodder | 0,01 | 0,01 | 0,04 | 0,00 | 0,01 | 0,03 |
| 🟦 Fossil energy | 0,14 | 0,08 | 0,34 | 0,16 | 0,11 | 0,19 |

**Figure 5-1. Global warming potentials for different BERAS-farm groups and for Swedish average agriculture,** ***kg $CO_2$ equivalents per kg products exported***

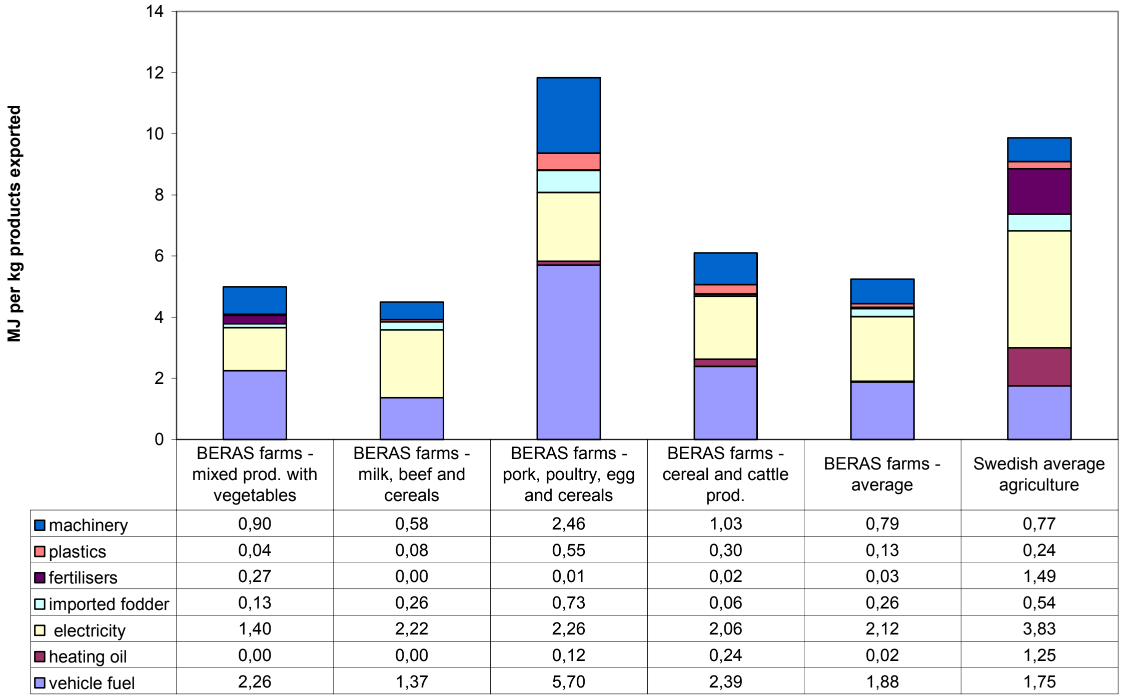


| | BERAS farms - mixed prod. with vegetables | BERAS farms - milk, beef and cereals | BERAS farms - pork, poultry, egg and cereals | BERAS farms - cereal and cattle prod. | BERAS farms - average | Swedish average agriculture |
|---|---|---|---|---|---|---|
| ■ Soil | 216 | 157 | 163 | 121 | 160 | 250 |
| ■ Animals | 1 725 | 1 867 | 681 | 458 | 1 385 | 884 |
| □ Plastics | 3 | 5 | 7 | 8 | 6 | 10 |
| □ Imported fertiliser/manure | 166 | 0 | 1 | 98 | 22 | 562 |
| ■ Imported fodder | 29 | 35 | 32 | 4 | 30 | 69 |
| ■ Fossil energy | 582 | 321 | 280 | 249 | 321 | 511 |

**Figure 5-2. Global warming potentials for different BERAS-farm groups and for Swedish average agriculture, *kg $CO_2$ equivalents per hectare***

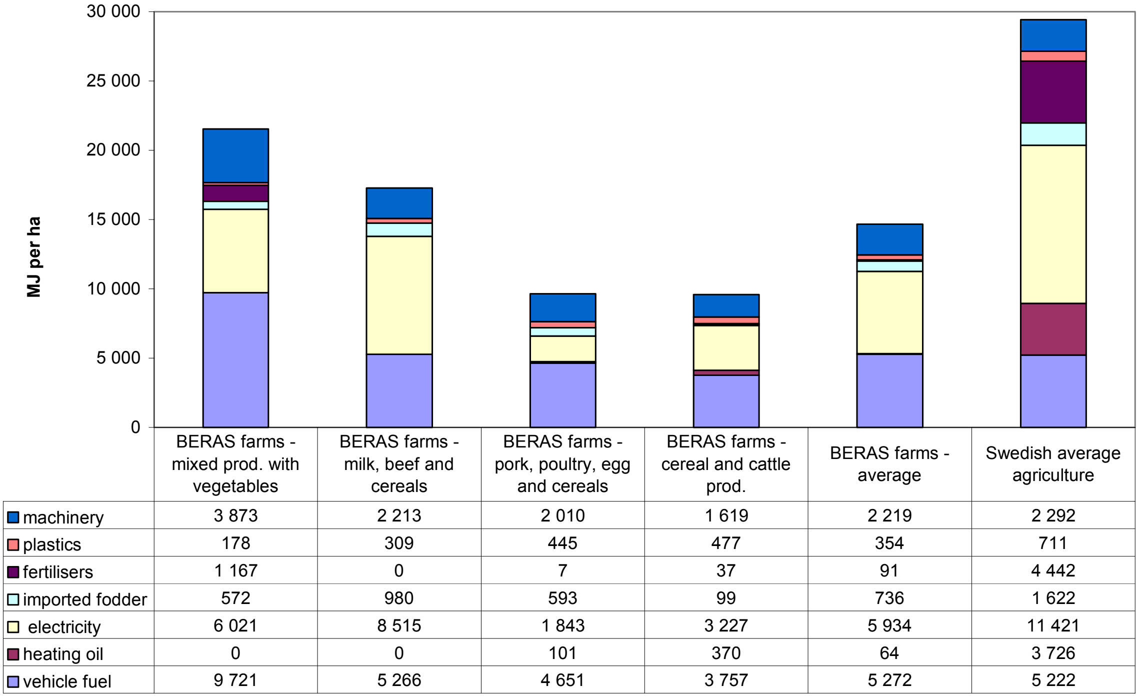
The consumption of primary energy resources is shown in Figure 5-3 and Figure 5-4. Calculated both per kg products and per hectare, the consumption is substantially lower on the average BERAS-farm compared to average Swedish agriculture. The most important reason is the lower use of heating oil (for drying of grain), fertilisers and electricity. The lower use of heating oil may be due to a lower rate of on-farm drying but this was not investigated. If that is the case, then that oil would be used in the food processing component instead and therefore, from a systems perspective, should not be included in the calculated difference. Further, for both vehicle fuels and fire oil the statistical data used for Swedish average agriculture also comprise forestry and fishery why these values probably are somewhat over-estimated. On the other hand, non-agricultural fuel use is included in the BERAS-farm data too making also those somewhat over-estimated. Even when considering the uncertainties, the difference is still obvious. The different levels in electricity consumption were not possible to explain within the study.

The very large diesel consumption in the BERAS "Pork, poultry, egg"-group is also noteworthy. This group is clearly more energy resources demanding than other farm production types. This calls into question the common opinion that meat production from monogastric animals like pigs and poultry is more energy efficient. However because there are only two such farms in this group, it is not possible to conclude from this study whether these results are due to chance or some other factor.



| | BERAS farms - mixed prod. with vegetables | BERAS farms - milk, beef and cereals | BERAS farms - pork, poultry, egg and cereals | BERAS farms - cereal and cattle prod. | BERAS farms - average | Swedish average agriculture |
|---|---|---|---|---|---|---|
| machinery | 0,90 | 0,58 | 2,46 | 1,03 | 0,79 | 0,77 |
| plastics | 0,04 | 0,08 | 0,55 | 0,30 | 0,13 | 0,24 |
| fertilisers | 0,27 | 0,00 | 0,01 | 0,02 | 0,03 | 1,49 |
| imported fodder | 0,13 | 0,26 | 0,73 | 0,06 | 0,26 | 0,54 |
| electricity | 1,40 | 2,22 | 2,26 | 2,06 | 2,12 | 3,83 |
| heating oil | 0,00 | 0,00 | 0,12 | 0,24 | 0,02 | 1,25 |
| vehicle fuel | 2,26 | 1,37 | 5,70 | 2,39 | 1,88 | 1,75 |

**Figure 5-3. Consumption of primary energy resources for different BERAS-farm groups and for Swedish average agriculture,** ***MJ primary energy resources per kg products exported***



| | BERAS farms - mixed prod. with vegetables | BERAS farms - milk, beef and cereals | BERAS farms - pork, poultry, egg and cereals | BERAS farms - cereal and cattle prod. | BERAS farms - average | Swedish average agriculture |
|---|---|---|---|---|---|---|
| machinery | 3 873 | 2 213 | 2 010 | 1 619 | 2 219 | 2 292 |
| plastics | 178 | 309 | 445 | 477 | 354 | 711 |
| fertilisers | 1 167 | 0 | 7 | 37 | 91 | 4 442 |
| imported fodder | 572 | 980 | 593 | 99 | 736 | 1 622 |
| electricity | 6 021 | 8 515 | 1 843 | 3 227 | 5 934 | 11 421 |
| heating oil | 0 | 0 | 101 | 370 | 64 | 3 726 |
| vehicle fuel | 9 721 | 5 266 | 4 651 | 3 757 | 5 272 | 5 222 |

**Figure 5-4. Consumption of primary energy resources for different BERAS-farm groups and for Swedish average agriculture,** ***MJ primary energy resources per hectare***

## Discussion

Using Swedish average agriculture as being representative for the conventional food producer for Swedish consumption in the global warming and energy use impact assessment is a somewhat weak point in the comparison. The data available are not fully comparable to the data obtained from farm-level records since statistics usually are not fully capturing all details. For this reason the estimated differences are probably conservative. For example a system's expansion to include imports and exports in the calculations probably would work in favour of ecological agriculture since both Johansson (2005) and Engström (2004) show a large dependence of imported animal feed in conventional agriculture – which is not the case for the BERAS-farms. The fodder imported on the BERAS-farms originates mainly from other Swedish farms.

## *Transports of locally produced food in Järna*

*Christine Wallgren, Center for Environmental Strategies Research (fms), Sweden*

This sub-study describes how locally produced and consumed food in Järna, Sweden, are transported, and how much fossil fuel this transportation uses. The food products covered by the study include vegetables, potatoes and other root crops from four local growers; milk and dairy products from Järna Mejeri; bread from Saltå Kvarn; and meat from farms in the vicinity of Järna. These products are collected from the different producers and delivered to stores, schools and other large kitchens both in and around Järna and in Stockholm (about 60 km away).

### Method

Data collected on the transport of these goods included vehicles used, routes taken, distances, amount of products transported, and fuel used. Energy use has been calculated as MJ/kg product delivered. Only direct energy use was counted and transports of necessities and ingredients other than the main raw products were usually omitted. If included this is commented in the text. The results have been compared to the transportation of equivalent products in today's conventional (large-scale) food system. Data used for comparisons to the conventional system have in most cases been earlier reported in Carlsson-Kanyama et al. (2004).

All calculations are based on data for the year 2004 and/or measurements performed during the spring of 2005. For some basic data that was not available, estimations have been made and the assumptions on which these are based are presented in the report.

Three case studies of small-scale, ecological and local production and distribution are included:

1. Saltå Kvarn (mill and bakery). They buy grain from ecological farms in Järna and in the south-central part of Sweden and produce cereal products and bread that is sold all over Sweden. The transport of bread to consumers in Järna and Stockholm are included in this study.
2. Järna Odlarring (a local farmer's cooperative). They buy and sell both farm fresh vegetables and root crops from four farms in Järna (during the season), and meat from ecological beef producers in Järna (all year around). These products are sold in and around Järna and in Stockholm.
3. Järna Mejeri (a farm-size dairy). They collect milk from two dairy farms in Järna and produce and sell milk, yoghurt and cheese in Järna and Stockholm.

#### *Data collection*

Data for the transportation of vegetables have been collected from the bookkeeping for Järna Odlarring 2004, which records the amounts of vegetables sold daily. Because the vegetables are harvested and sold on the same day there is no intermediate storage and no losses. The amount collected is equivalent to the amount sold. Possible farm losses are ploughed back into the soil. Weekly averages of deliveries were calculated from the raw data. Transport data was calculated for two different delivery routes during three average seasons - early, mid and late seasons. When vegetables and meat were co-transported this was taken into consideration. Two different vehicles were used. The average fuel consumptions for each was calculated on a yearly basis. The route distances were taken from the vehicle meters.

Data for the meat transports were obtained from both the slaughterhouse that transported the animals from the farms to the slaughterhouse and from Järna Odlarring that delivered the meat to consumers/shops. Average data for distances and fuel consumption and a combination of detailed and yearly average data for the number of animals was used. The volumes and delivery distances were recorded during two weeks in April 2005. The routes included two transports from the slaughterhouse combined with two deliveries to customers in the vicinity of Järna, and two deliveries to Stockholm. The amounts were recorded as the vehicles were loaded and distances driven were recorded for each trip. The same vehicles used for transporting vegetables were used for meat and the fuel consumption and distances were assumed equal in both cases.

During the winter season, only meat is transported in the vehicles. During the early and late vegetable seasons, vegetables and meat are transported together as often as possible. Strict rules concerning packaging and temperatures have to be followed. In order to separate the energy used proportionally for vegetables and meat allocation per weight was used. .

For milk and dairy products, data collection was performed during April 2005. The routes include collection of milk from one farm in Järna (the dairy is situated at the other farm), and deliveries to customers, two in and around Järna and one to Stockholm. These three routes are about the same every week all year around. The distances were recorded for each route. The fuel consumption was measured by filling up the vehicles before and after each trip. Two different vehicles were used. The amounts of products were recorded at each loading occasion.

Calculations for the bread transports were based on average deliverances during one year. This was assumed appropriate since the bread deliveries to Järna are relatively constant over the year. The transports included in this study are those performed by the mill themselves using the company's own vehicle. They deliver to grocery stores in Järna and Stockholm. Bread delivered to other wholesale distributing channels, primarily to COOP, is omitted in this study.

### ***Energy use calculations***

For each transport, data for fuel use, distance and the amount of products were collected as described above. Only diesel-fuelled vehicles were used. Energy use was calculated in MJ/kg product. First, the fuel use per kilometer was multiplied by the number of kilometers per trip – giving the fuel use per trip in litres. By multiplying with 35.86, the energy content of 1 litre diesel, energy use per trip in MJ/trip was calculated. Lastly, the energy use per trip was divided by the number of kilos of products transported – giving energy use per kg product transported. These calculations were performed for meat, vegetables, milk and dairy products, and bread separately.

Comparative data for transport of similar conventional products have been collected from several sources, all of which are referred to in Carlsson-Kanyama et al. (2004).

## Results and discussion

The results are presented in text here and in diagrams together with the comparative data on conventional products in the following sub-chapter.

### Saltå Kvarn

Saltå Kvarn produced 11000 loafs of bread per week (production on 5 days) during 2004 from flour milled in their own mill. The grain was bought from about 20 farms, in Järna as well as in the south and central part of Sweden. The largest farm is situated outside Lidköping in the west of Sweden, some 330 km away. Grain is also bought from a wholesaler. The farms around Järna delivers about 500 ton. In total, Saltå Kvarn buys about 4000 ton per year. Everything is transported by truck or tractor and wagon.

The weight of the bread produced in the bakery was 6600 kg per week giving 343 ton per year. To produce one kilo of bread about 0.78 kilo grain is used. (1.3 kilo of grain gives one kilo of flour and about 0.6 kilo flour is used per kilo bread.) In order to produce 343 tons of bread per year, 267 tons of grain are used. Because this amount is well within what the Järna farms deliver, only the local grain in-transports have been used in the calculations.

#### *Transportation of ingredients*

Locally produced grain is transported by the farmers by tractor and wagon. The fuel consumption is 10-12 litre diesel per hour. The grain is transported directly from the field to a silo at Järna Kvarn for drying. This transport is between 3 and 5 km and takes approximately 26 minutes round trip. Assuming the average load was 13 tons this gives 4.8 litre diesel per load, 0.013 MJ per kg grain and about 0.01 MJ per kg bread. After drying, the grain is transported by truck to storage in Tystberga 42 km away (84 km round trip). This transport used 0.026 MJ/kg bread. Together the grain transports used 0.036 MJ per kg bread.

Other ingredients such as dried fruit and seeds make up about 7 % of the bread weight. Some of them are imported from e.g. Turkey. A rough estimate, assuming that most of them originate in Europe and use 5 MJ/kg for transports, gives 0.35 MJ per kg bread. Hypothetically, it could of course be argued that the ingredients could be exchanged for locally produced berries and seeds but we have chosen to include the energy use for the imported ingredients.

The total energy for **transportation of ingredients** in this case was about **0.4 MJ per kilo bread**.

#### *Bread deliveries*

Of the bread produced, about 16 tons were delivered locally in and around Järna. 187 tons were delivered in their own vehicles to Stockholm and 140 tons were collected by distributors at the bakery. Saltå Kvarn also sells flour, groats, muesli and imported products like seeds and dried fruit but as these are all transported by distributors, they are not included in this study.

The local deliveries were made with a small lorry that consumes 15 litres diesel per 100 km, to two grocery stores in Järna (ICA and COOP). The distance is 8 km round trip. About 100 loafs (55 kg) were delivered each time. No other goods were transported on these occasions and the vehicle returned to the bakery empty. The fuel consumption was thus 1.2 l/trip, making the energy use 43 MJ/trip and **0.78 MJ per kg bread** delivered.

Deliveries to Stockholm were made five days a week with the same vehicles used for local deliveries. About 1200 loafs weighing 720 kg were delivered on each trip. The average fuel consumption was the same as for the local deliveries (15 l/100 km) and the distance was 150 km. The fuel consumption was 22.5 litres diesel, making 807 MJ per trip and **1.12 MJ per kg bread** delivered. Also here, no other goods were transported on these trips and the car came back empty back to the bakery. The car was, however, full when starting from the bakery, so no extra space was available on the trip to Stockholm.

### *Energy use per kilo bread*

The conclusion is that the **total energy use for transport of bread was 1.2 MJ per kg bread** delivered locally in Järna. Using 100 % locally produced ingredients and local storage would lower the energy use by about 0.3 M//kg bread (a portion of 0.35 and 0.026), resulting in a possible energy use of 0.9 M//kg bread. However, the most important factor influencing the amount of energy used is the amount transported each trip. If the volume had been 300 loaves instead of 100, the energy use would be a third. The second most important factor is the vehicle that is used. Using a smaller car with fuel consumption of 7 l/100 km would halve the energy use.

This can be compared to the transport of conventional bread. LCA-studies show 1.0 MJ/kg bread (hamburger bread in Stockholm) (Carlsson-Kanyama and Faist, 2000) and 3.8 MJ/kg bread (Johannisson and Olsson, 1998).

## Järna Odlarring

Järna Odlarring has fixed delivery routes for meat and vegetables but delivers also at other times and places in order to be flexible and respond to consumer demands. Not all routes are, therefore, optimal from an energy efficiency point of view. Two vehicles are used; a Citroën Berlingo model 1999 with a fuel consumption of 7 litre diesel/100 km (cooling cabin) and a Fiat Ducato model 2000 with a fuel consumption of 12 litre diesel/100 km. Both vehicles are run without a trailer.

### *Livestock transportation*

Livestock were collected on six farms around Järna and transported to a small slaughterhouse in Stigtomta outside Nyköping some 60-70 km away. These transports were performed by the slaughterhouse company. Collections were made once every other week and usually included 2 - 4 cattle and, during October-November, about 10 lambs. In addition 10 calves from these farms were collected for slaughter each year. This makes it a yearly total of about 75 cattle, 40 lambs and 10 calves.

The vehicle used was a Scania animal transport lorry of the smallest size, consuming 30-50 litre diesel/100 km. The maximum load is 13 cattle or 50 lambs. As it is not allowed to transport animals from ecological and conventional farms together, the lorry was usually not full. The distance for each trip varied depending on which farms delivered animals. An average round trip was estimated to 156 km.

### *Transportation of meat*

All deliveries of meat from the slaughterhouse to the Järna consumers were done by Järna Odlarring. The meat was delivered in closed packages, in the same vehicles that transported vegetables. The beef was cut in ready-to-eat pieces and vacuum-sealed and was therefore allowed to be co-transported with vegetables. The lambs were cut with bones and not vacuum-sealed but instead packed in plastic bags that were put in cardboard boxes. These were not allowed to be co-transported with vegetables. A thorough cleaning of the vehicles had to be performed between the transports. When possible the small van was used. The larger lorry was used for about half of the tours to Stockholm.

On Wednesday, even weeks, meat was collected at the slaughterhouse and delivered to the two grocery stores in Järna. Some meat, that was not possible to sell immediately, was put in cool and cold storages in Järna. About 23 trips from the slaughterhouse are performed per year. On Wednesdays, odd weeks, meat from their own storage was delivered to the two stores in Järna and to stores in Stockholm. The routes were about the same all year round. Deliveries to large institutional kitchens in Järna were performed on Tuesdays every week. The orders were quite varied, thus no average trip are possible to set.

Each head of cattle gives about 140 kg bone-free beef. A calf gives about 60 kg. An average lamb gives 17.5 kg meat including bones. This gives an annual total of about 10.5 ton beef, 600 kg calf meat and 700 kg lamb meat (total 11800 kg meat per year). Per delivery this is about 480 kg beef and calf meat. Adding the 700 kg lamb meat produced during October-November, an average of 510 kg meat was transported per delivery.

During the autumn 2004, a trial to slaughter and deliver pig meat was carried out. This has not been included in the calculation. If sales are high enough it is assumed that 3 pigs every other week could be added to the deliveries. These additional kilos would probably improve the energy efficiency of meat transportation.

Calculations of energy use for animal and meat transportations were performed in three steps:

1. The energy used for transporting the animals to the slaughterhouse was 156 km per trip x 0.4 l diesel per km x 35.86 MJ per l diesel / 510 kg meat per trip = **4.4 MJ per kg meat**
2. The energy used for fetching the meat at the slaughterhouse was 156 km per trip x 0.103 l diesel per km x 35.86 MJ per l diesel / 510 kg meat per trip = **1.1 MJ per kg meat**
3. The energy used for deliveries to the Järna customers was **0.45 MJ per kg meat**. This value is a weighted average of different routes and seasons where the energy use has been allocated between meat and vegetable transports. (The calculations can be obtained in an Excel-sheet from the author.

### *Energy use per kg meat*

Together this gives a total of **6 MJ per kg meat** delivered in Järna. The energy used for the delivering meat to Stockholm is 5.6 MJ per kg meat, giving a total of around 11 MJ per kg meat.

The addition of three pigs every other week would lower the energy use per kilo meat to 3.9MJ. If the volumes increased even more to a level where the animal transport lorry was full each trip, the energy use would be lowered to about 1 MJ per kg meat. The total energy use should then be around 4 MJ per kg meat delivered in Järna.

Energy use for conventional animal and meat transports, collected from different LCA-studies, are presented in Table 5-4. The Järna meat transports seem to be much more energy demanding in comparison to literature data for conventional meat transports. However, they are in the same range as the data for meat in hamburgers and about half of the value for meat transported from Latin America.

**Table 5-4. Energy use for conventional meat transports, from other studies.**

| Examples | Reference | MJ per kg meat |
|---|---|---|
| Meat from Sweden | Johannisson and Olsson (1998) | 0.45 |
| Meat from Sweden | Edsjö (1995) | 0.97 |
| Meat from Linköping to Stockholm | Sunnerstedt (1996) | 0.46 |
| Meat in hamburgers in Stockholm [1] | Carlsson-Kanyama and Faist (2000) | 5.7 |
| Meat from Ireland to Stockholm | Sunnerstedt (1996) | 1.2 |
| Meat from Latin America | Wallgren (2005) | 12 |

[1] Transport distance 1000 km

### *Transportation of vegetables*

Vegetables and root crops collection from growers was done during the same trip as delivery to consumers so no intermediate storage was needed. In 2004 the deliveries started the last week in May. During this first period, the early season, which lasted to 1st July, one delivery route was made per week to customers in and around Järna. This trip was 48 km.

During the main season, July to September, three deliveries were made each week. Two of these, on Tuesdays and Thursdays went to the Järna area, and this route was 33 km long. The third trip of 123 km, on Wednesdays, delivered vegetables to Stockholm. The total distance was 189 km per week.

During the late season, October and November, one local trip in Järna was made each week and one trip to Stockholm every other week. Distances were as before. A few after-season deliveries were made during December of root crops and vegetables stored at Skilleby farm, one of the producers.

The harvest, and therefore the deliveries, varied greatly during these three seasons. The amount delivered weekly is shown in Figure 5-5. In total, 21500 kg were delivered during 2004. The average weekly deliverances for the three seasons are shown in Table 5-5.

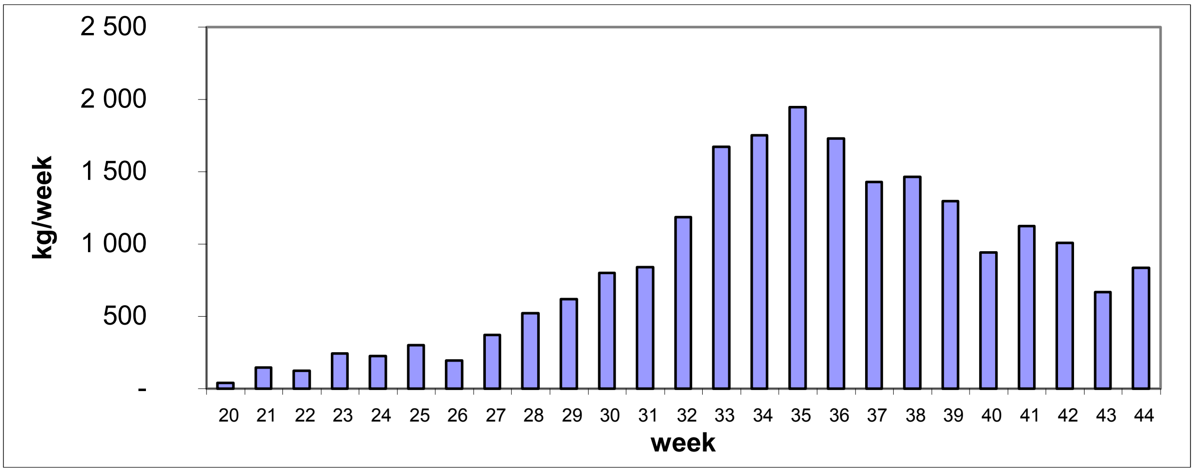


**Figure 5-5. Weekly deliverances to Järna and Stockholm of vegetables and root crops by Järna Odlarring from week 20 to week 44 during 2004.**

**Table 5-5. Average weekly deliveries for the three seasons.**

| Period | Number of weeks | Weight per period | Average weight per week |
|---|---|---|---|
| Early season | 9 | 1653 | 184 |
| Main season | 12 | 14561 | 1213 |
| Late season | 5 | 4579 | 925 |
| 2004 | 26 | 21498 | 827 |

### *Energy used for transportation of vegetables*

The energy used was calculated as a weighted average of the deliveries during the three seasons, as given in Table 5-5 and the estimated fuel consumption for the different routes. The co-transportation of vegetables and meat was also taken into consideration. The total energy used for the local transportation of vegetables and root crops in the Järna area worked out to **0.3 MJ per kg product**. The equivalent for the deliveries to Stockholm was 5.9 MJ per kg product.

Comparisons to LCA-studies show some results in the same range but most of them show a larger energy use per kg product (Table 5-6).

**Table 5-6. Energy use for transportation of vegetables consumed in Stockholm, results presented in other studies.**

| **Origin** and product | **Energy intensity, MJ/kg** | **Reference** |
|---|---|---|
| **Sweden/Denmark** | | |
| Potatoes | 0.8 | Carlsson-Kanyama & Boström-Carlsson (2001) |
| Potatoes | 0.6 (locally 0.06-0.15) | Sunnerstedt (1994) |
| Tomatoes | 0.8-0.9 | Carlsson-Kanyama (1997) |
| Tomatoes | 0.6 | Sunnerstedt (1994) |
| Lettuce [1] | 1.5 | Carlsson-Kanyama & Faist (2000) |
| Carrots | 0.8-1.0 | Carlsson-Kanyama (1997) |
| Carrots | 0.17 (Gotland) | Sunnerstedt (1994) |
| Apples | 0.9-1.5 | Stadig (1997) |
| Apples | 0.6 | Sunnerstedt (1994) |
| **Europe** | | |
| Tomatoes | 1.8-3.9 | Carlsson-Kanyama (1997) and Sunnerstedt (1994) |
| Tomatoes, by air | 50 | Carlsson-Kanyama (1997) |
| Carrots | 1.2-3.2 | Carlsson-Kanyama (1997) and Sunnerstedt (1994) |
| Apples | 2.8 | Stadig (1997) |
| **Other continents** | | |
| Apples | 1.8-2.1 | Sunnerstedt (1994) |
| Apples | 5.6-7.7 | Stadig (1997) |

[1] Lettuce served with hamburgers in Stockholm. Transport distance 1200 km. (Carlsson-Kanyama & Faist 2000)

## Järna Mejeri

### *Transport of milk to the dairy*

Transport of milk to the dairy is carried out every second day all year around. The Peugeot 1999 with a cooler tank and trailer used for these transports had a fuel consumption of 8 litres per 100 km. The milk was collected at two farms and this round trip was 9 km. On average, 1000 litres were collected at Nibble and 800 litres at Yttereneby on each occasion. Each trip used 0.72 litre diesel, giving an energy use of 25.8 MJ per 1800 litres. Assuming that one litre milk is equivalent to one kilo milk, this results in 0.014 MJ per kg milk.

### *Deliveries of dairy products*

Deliveries of milk and dairy products to customers were made with two different vehicles, the Peugeot mentioned above and a diesel fuelled Daewoo 2000 with a fuel consumption of 12 litre per 100 km. There were three different delivery routes.

<u>Route 1 – Järna and vicinity.</u> The route is 39 km and the Peugeot (8 l/100 km) was used. Starting at the dairy, it stopped at Nibble farm, Saltå mill, Mossvägens Livs, Konsum Järna, ICA Järna, Konsum Hölö, and then returned to the dairy. This trip was made once a week. The goods on the measuring week (week 11) included 350 kg drinking milk, 108 kg sour-

milk, 78 kg yoghurt and 10 kg other products (but no cheese), giving a total of 545 kg. The fuel consumption was 3.1 l diesel. This works out to 0.204 MJ per kg. Adding the energy used for the transport of milk to the dairy (0.014 MJ/kg), the total energy works out to 0.22 MJ/kg.

Route 2 – Järna and vicinity. This route is 57 km and the Daewoo (12 l/100 km) was used. Starting at the dairy, it stopped at Nibble farm, ICA Järna, Konsum Järna, Konsum Gnesta, Konsum Hölö, and The Culture house in Ytterjärna before returning to the dairy. This trip was made twice a week and the fuel consumption was 6.8 litre diesel per trip. On the week measurements were taken 620 kg products were delivered, giving an energy use of 0.39 MJ per kg product. Adding the energy used for the transport of milk to the dairy (0.014 MJ/kg), the total energy works out to be 0.40 MJ/kg.

Route 3 – to Stockholm The route is 195 km and the Daewoo was used to deliver to about 20 customers. 23.4 litre diesel were used. The deliveries included 268 kg milk, 70 kg sour-milk, 136 kg yoghurt, 72 kg cheese and 29 kg other products, in total 585 kg. This works out to 1.43 MJ per kg. Adding the energy use for the transport of milk to the dairy (0.014 MJ/kg) the total works out to be 1.44 MJ/kg.

### *Energy use per kg dairy product*

The weighted average of the energy use for the **locally delivered dairy products** (Route 1 and 2) was **0.32 MJ per kg**.

Results from LCA-studies of conventional production are shown in Table 5-7. One of these show results in the same range as the Järna case but most of them report substantially higher energy demand for transports of dairy products.

**Table 5-7. Energy use for transports, results from other studies.**

| **Origin** and product | **Energy intensity, MJ/kg** | **Reference** |
|---|---|---|
| **Sweden/Denmark/Finland** | | |
| Yoghurt | 0.30-0.38 | Sunnerstedt (1994) |
| Cheese | 1.7 | Berlin (2001) |
| Cheese | 1.2 | Sunnerstedt (1994) |
| Cheese [1] | 9 | Carlsson-Kanyama & Faist (2000) |
| **Europe** | | |
| Yoghurt | 2.1 | Sunnerstedt (1994) |
| Cheese | 1.9 | Sunnerstedt (1994) |

[1] Cheese served with hamburgers in Stockholm. Transport distance 1000 km.

## *Small-scale food processing industries in Järna*

*Olof Thomsson, Swedish Biodynamic Research Institute, Järna Sweden*

This sub-study investigated the use of energy and packaging in small-scale food processing industries for bread, vegetables and root crops, dairy products, and meat. The industries studied are the same businesses studied in the transport sub-study: a mill and bakery (Saltå Kvarn), a farmers' cooperative meat and vegetables wholesaler (Järna Odlarring), a farm-size dairy (Järna Mejeri), all situated in the vicinity of Järna, and a small slaughterhouse (Stigtomta Slakteri) situated some 65 km away from Järna. These are compared to "conventional" large-scale food processors.

## Method

Data for direct energy use, use of packaging materials (in-direct energy use), and production in the small-scale industries were collected from the bookkeeping records and through interviews with responsible persons at each enterprise for the year 2004.

Direct energy use, electricity, heating oil and fossil gas were inventoried separately in order to be able to calculate the consumption of primary energy resources and global warming impact reported in the next section. For the indirect energy use, the production and inherent energy of packaging materials were included (Audsley et al. 1997; Habersatter et al. 1998). Also here electricity and fossil fuels were recorded separately. Energy use and recovery from packaging waste management, from the import of other raw materials and from water production and wastewater treatment have not been included.

Data for similar products produced in large-scale industries were mainly obtained from LCA Livsmedel (2002). This was a project within the Swedish cooperative food industry that made seven life cycle assessments (LCAs) on food products. The complete studies have not been published but the aggregated results have been presented in Swedish in a popular publication and on some of the companies' websites. The products studied included: drinking milk (1.5 % fat), beef (from dairy farms, which represent 70 % of the Swedish beef production), pork, chicken, hamburger bread, potatoes, and iceberg lettuce. Here the waste management of packaging material was included.

## Results and discussion

The direct energy use and indirect energy in MJ per kg product for bread, vegetables and root crops, meat, and dairy products in the Järna food industries and in large-scale food industries are shown in Table 5-8. These comparisons show no clear trend as to whether small or large-scale food processing is more energy efficient than the other. It could be expected that large-scale industries would use less energy per kg product due to the large-scale efficiency factor. This appears to be the case for meat and dairy products, while for bread and vegetables it is the opposite. It is important to remember that there are large differences in the reported energy use in the literature and such differences also probably occur in practice. The use of energy in the different sectors is discussed in further detail in the separate sections below.

**Table 5-8. Energy use in processing of four different product groups for conventional food systems and small-scale local food systems, *MJ per kg product***

| | | Direct use electricity | Direct use fossil fuel | Packaging electricity | Packaging fossil fuel | Total |
|---|---|---|---|---|---|---|
| bread | conventional[10] | 3.8 | 0.5 | 0.4 | 1.7 | 6.4 |
| | Järna[11] | 1.3 | 2.2 | 0.2 | 1.6 | 5.3 |
| vegetables, root crops and potatoes | conventional[12] | 0.2 | 0.0 | 0.7 | 1.1 | 2.0 |
| | Järna | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| meat | conventional[13] | 2.6 | 1.4 | 0.1 | 2.9 | 7.0 |
| | Järna | 5.2 | 0.0 | 0.3 | 3.3 | 8.8 |
| dairy products | conventional[14] | 0.2 | 0.2 | 0.2 | 1.0 | 1.6 |
| | Järna | 0.9 | 0.0 | 0.0 | 1.3 | 2.2 |

---

[10] hamburger bread (LCA Livsmedel 2002)

[11] all kinds of bread

[12] average of potatoes and lettuce (LCA Livsmedel 2002)

[13] average of beef and pork, since that is what is slaughtered in Stigtomta (LCA Livsmedel 2002)

[14] drinking milk (LCA Livsmedel 2002)

### *Bread*

The bakery at Saltå Kvarn used less fossil energy per kilo bread than the conventional case (production of hamburger bread). Saltå bakery makes many different kinds of bread. Saltå also uses some fire-wood (some 500 $m^3$ wood annually) but as this is assumed to be $CO_2$-neutral it was not included in the calculations. In scenario simulations based on other sources, presented in Thomsson (1999), the direct energy use in bakeries ranged from 1.6 to 3.8 MJ per kg bread and indirect energy use in packaging from 1.2 to 6.3 MJ per kg bread (This was reduced to 0.5-2.5 when the packaging material was recycled and incinerated). In total the range in that study was 2.8 to 10.1 MJ per kg bread (or 2.1 to 6.3 when the recycling was included). Taking into consideration this range the results from Järna are even more positive. On the other hand, if recycling of the packaging material (500 $m^3$ wood) had have been counted in the Järna study the total would have increased to 4.5 MJ per kg bread.

### *Vegetables and root crops*

The processing of vegetables and root crops did not use any large amounts of energy. In Järna, most products were harvested and delivered on the same day and little processing was done. Also because this was a seasonal activity only carried out during the growing season, no heated buildings was needed. The energy used by the office was not included, as this seemed to be the case in the conventional study. Concerning packaging, the major energy use was for the lettuce in the conventional example. The lettuce was put into plastic bags (primary packaging) and then transported in single-use cardboard boxes (secondary packaging). In the Järna case, most of the vegetables were transported with only secondary packaging consisting of re-usable plastic boxes.

### *Meat*

As might be expected conventional meat processing used less energy in the plant (25 % less). Since Stigtomta is a small slaughterhouse specialised in “individual slaughter”, i.e. farmers are guaranteed to get back their own animal carcasses if they want, that difference is actually surprisingly small. Concerning the packaging the difference is around 15 percent.

### *Dairy products*

The energy used in the small-scale Järna dairy was more than double that of the conventional example. There may be a bias due to the fact that the Järna dairy produced a lot of cheese while the conventional case to which it was compared was for milk only. About 10 kg milk is used to produce 1 kg cheese so this increases the energy used per kg product compared with milk.

## *Global warming impact and primary energy consumption in a local food chain in Järna*

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This section describes emission of gases that contribute to global warming and consumption of primary energy resources in the transportation and processing parts of the food system described above.

## Method

The environmental impacts were assessed as described at the beginning of this chapter. The data on the use of energy and packaging collected in the transportation and processing studies were the starting point for the calculations. The electricity used was assumed to be produced in the same way as the Swedish average – i.e. half hydropower and half nuclear power and only a minor portion from fossil fuels. Concerning the emission of global warming gases in the production of packaging material, data from Audsley et al. (1997) and Habersatter et al. (1998) were used.

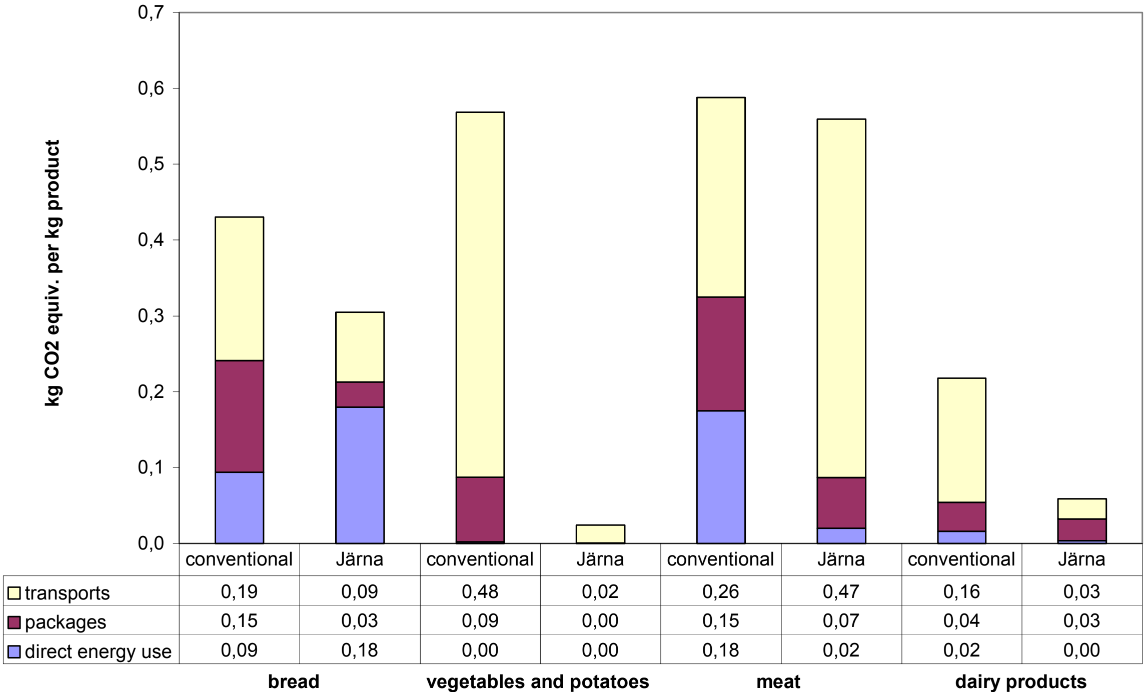
The results are presented as Global Warming Potentials (GWP) with the unit kg $CO_2$-equivalents per kg product and MJ primary energy resources per kg product.

## Results and discussion

When looking at the GWP for the combined processing and transportation of various products, the difference between the conventional and the Järna system is substantial for bread, vegetables & root crops and dairy products – especially for the latter two (Figure 5-6). The very inefficient transportation of the meat produced in Järna and slaughtered in Stigtomta makes the GWP equal to the conventional. Somewhat larger volumes, as discussed in the transportation study, would improve the efficiency of the Järna alternative making it better than the conventional system..

It should, however, be remembered that the data for the conventional processing is not entirely comparable to the Järna cases, and the data for transportation from different literature references varies greatly. The results of this comparison can only be taken as an indication of differences that may occur. Both the conventional and the local small-scale systems can be better or worse in terms of their global warming impact. For example the choice of energy carrier is a very important factor affecting their impact. Comparing the results for meat in Table 5-8 and Figure 5-6 can serve as a good example. The energy used in the conventional plant consisted of 2.6 MJ electricity +1.4 MJ fossil fuels. This equals 4.0 MJ per kg meat. The Järna plant used 5.2 MJ electricity per kg meat. Although 30 percent more energy is used in the Järna plant, its GWP was only 90% of the conventional plant's impact. Looking at the bread baking alternatives, the comparison gives the opposite results. Because the conventional plant uses larger part electricity, the GWP of their direct energy use is only half that of Järna's. Had more environmental impact categories been chosen, it would have been possible to show a broader picture of environmental impacts. Unfortunately this was not possible within the framework of this project.

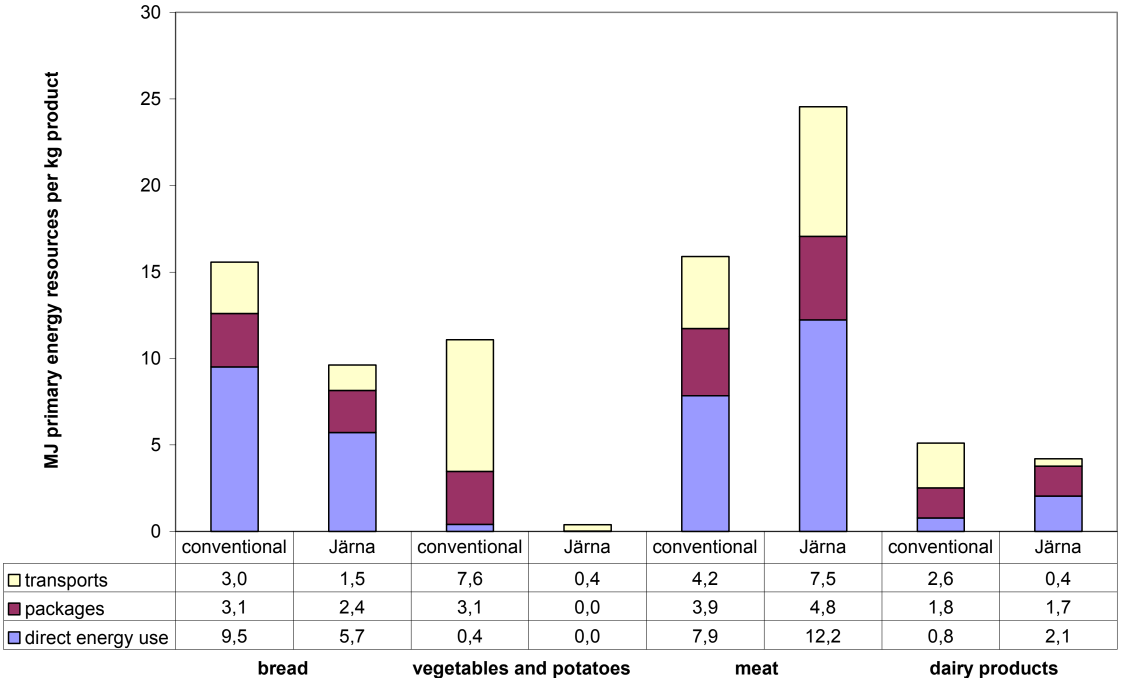
Concerning the GWP from packaging and transportation, these represent a reasonable difference since both packaging materials and fuels in principle are of equal origin.



| | conventional | Järna | conventional | Järna | conventional | Järna | conventional | Järna |
|---|---|---|---|---|---|---|---|---|
| ☐ transports | 0,19 | 0,09 | 0,48 | 0,02 | 0,26 | 0,47 | 0,16 | 0,03 |
| ■ packages | 0,15 | 0,03 | 0,09 | 0,00 | 0,15 | 0,07 | 0,04 | 0,03 |
| ■ direct energy use | 0,09 | 0,18 | 0,00 | 0,00 | 0,18 | 0,02 | 0,02 | 0,00 |
| | bread | | vegetables and potatoes | | meat | | dairy products | |

**Figure 5-6. Global warming potentials for conventional processing and Järna small-scale processing plants for different product groups,** ***kg $CO_2$ equivalents per kg products exported***

The general results for consumption of primary energy resources (Figure 5-7) show similar patterns as the GWP above. The exception is for meat processing, where the Järna case show a substantially larger consumption. This is partly due to the inefficient transportation but is also a result of the slaughterhouse using only electricity. While in Sweden this is “global warming friendly”, it does use a lot of primary energy resources. Also here, the contrary phenomenon can be observed for the bread processing cases.



| | conventional | Järna | conventional | Järna | conventional | Järna | conventional | Järna |
|---|---|---|---|---|---|---|---|---|
| ☐ transports | 3,0 | 1,5 | 7,6 | 0,4 | 4,2 | 7,5 | 2,6 | 0,4 |
| ■ packages | 3,1 | 2,4 | 3,1 | 0,0 | 3,9 | 4,8 | 1,8 | 1,7 |
| ■ direct energy use | 9,5 | 5,7 | 0,4 | 0,0 | 7,9 | 12,2 | 0,8 | 2,1 |
| | bread | | vegetables and potatoes | | meat | | dairy products | |

**Figure 5-7. Consumption of primary energy resources for conventional processing and Järna small-scale processing plants for different product groups,** ***MJ primary energy resources per kg product***

## Conclusions

The studies presented in this chapter show the potential for diminished global warming impact and lower use of primary energy resources through a systems change to Ecological Recycling Agriculture and to a more localised food industry. Because the examples presented are not always fully comparable due to lack of available data, both the conventional and the ecological/local cases could be worse or better than indicated here. For this reason, and because these issues of GWP and primary energy resource consumption are of such importance, more research is needed to be able to draw reliable conclusions that can form a clear basis on which decisions can be made.

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# 6. Biodiversity

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## *Introduction*

From 1950 to 1980 the use of pesticides as well as the use of artificial fertilizers increased in all countries around the Baltic Sea. It is also a well known fact that the reduction of singing birds in the agricultural landscape is connected to the arable intensification in the European countries.

Migratory and nesting birds dependent for food and shelter on wetlands and woodlands adjacent to agricultural fields, as well as the fields themselves, are exposed to pesticides by direct spraying or from drift. Agricultural pesticides can also have indirect effects on birds by reducing availability of food resources, nesting sites, and cover. Spring applications of pesticides often coincide with the breeding season of waterfowl and other species. From 1970 to 1998 the average population of farm land birds fell (bird index for 12 farmland specialist birds in Europe) with more than 40 %. (Donald et al. 2002)

Biodiversity in the agricultural landscape is affected by many factors also outside the farming systems. Especially non-cropped areas in less used agricultural land, like in the Baltic countries, have been important areas for many organisms during the last ten years. The maintenance of biodiversity in the agricultural landscape in the more intensely producing agricultural areas will depend on the preparation, reconstruction and management of wetlands, ditches, ponds and small habitats for soil and water living organisms, insects and birds. Non-use of pesticides will have a direct positive influence on pest insects but also on their predators and the diversity and abundance of weeds. This can be a competitor for agricultural crops, but would also be habitats for many other living organisms (Bengtsson et al. 2005).

It is difficult to compare the effects on biological diversity of ecological agriculture with conventional agriculture due to the influence of the large surrounding areas. Bengtsson et al. (2005) made a literature review of the effects of ecological agriculture on biodiversity and abundance of populations. It summarises that ecological farming systems usually increase the number of species. On average there was 30 % higher species richness compared to conventional farming systems. However, the results varied among the studies and 16 % of them actually showed a negative effect of ecological farming on species richness. In average, organisms were 50 % more abundant in ecological farming systems, but also here the results varied a lot between the studies and between organism groups. Birds, predatory insects, soil organisms and plants responded positively to ecological farming, while non-predator insects and pests did not. Based on the results the authors (Bengtsson et al. 2005) suggested that positive effects of ecological farming can be expected in intensively managed agricultural landscapes, but not in small-scale landscapes also having many other biotopes besides agricultural fields. They also suggested that measures to preserve and enhance biodiversity should be more landscape- and farm specific than in the regionalised studies.

## *Methodology*

Since the use of pesticides largely affects the biodiversity this study has focused on showing trends on pesticide use in the conventional agriculture around the Baltic Sea. Those trends are then discussed in comparison to the non-use of pesticides in ecological recycling agriculture.

## Results and discussion

Despite the support to ecological agriculture, environmental declarations and governmental environment goals no decrease in the use of pesticides was documented in the Nordic countries and in Germany during the last decade. In Germany pesticide use in agriculture was on the same level during the years from 1995 to 2003 (Figure 6-1) (Bundesamt für Verbraucherschutz, 2005) but the use of pesticides in Sweden even increased from 1224 ton (2 530 000 hectare doses) to 2084 ton active substances (4 605 000 hectare doses) in spite of the increase of the ecological agriculture from about 50 000 ha to 465 000 ha during the same time (Figure 6-2) (Statistics Sweden 2005).

In Estonia, Latvia and Lithuania the use of pesticides dropped down to a minimum after the Soviet collapse but the last years the pesticide use was increasing heavily again. Figure 6-3 shows the example of Latvia after 1995 (Kreismane, 2005).

Converting the whole agriculture in the Baltic Sea drainage area to ecological recycling agriculture would totally end the use of pesticides and thus enhance the biodiversity. The farms studied in the BERAS project can be models for how this can be achieved for different conditions in the different regions. Further studies of the biodiversity on the actual farms will be needed to say anything in detail about the positive effects such a conversion would have. If this conversion to ecological agriculture not will be realised it is very likely that the use of pesticides will increase from the very low level in the Baltic countries like Latvia and in Poland to the level of Sweden and Germany (Figure 6-4) due to the on-going intensification and industrialisation of the agriculture in these countries.

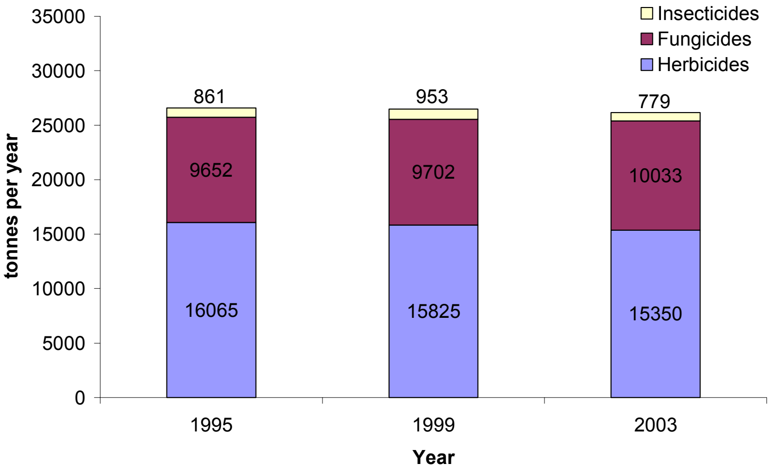
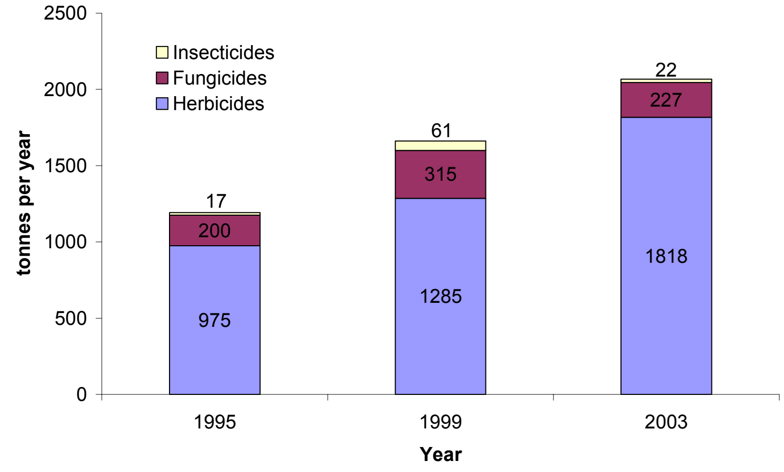


**Figure 6-1. Pesticide use in German agriculture 1995-2003,** ***tonnes of active substances per year and hectare doses per year.***



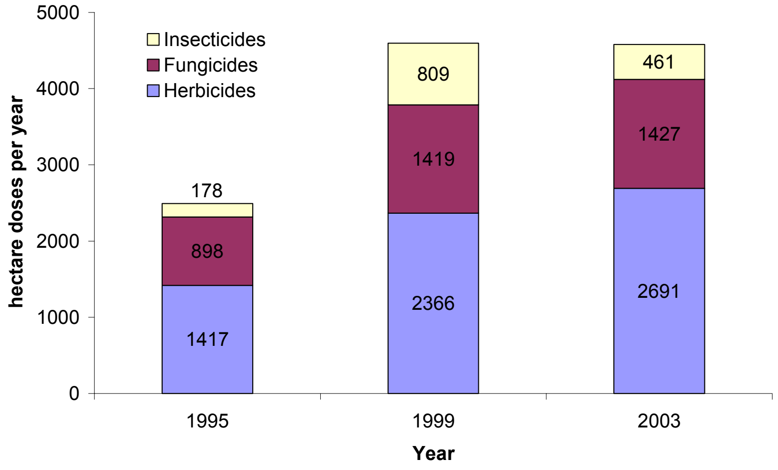


**Figure 6-2. Pesticide use in Swedish agriculture 1995-2003,** ***tonnes of active substances per year and hectare doses per year.***

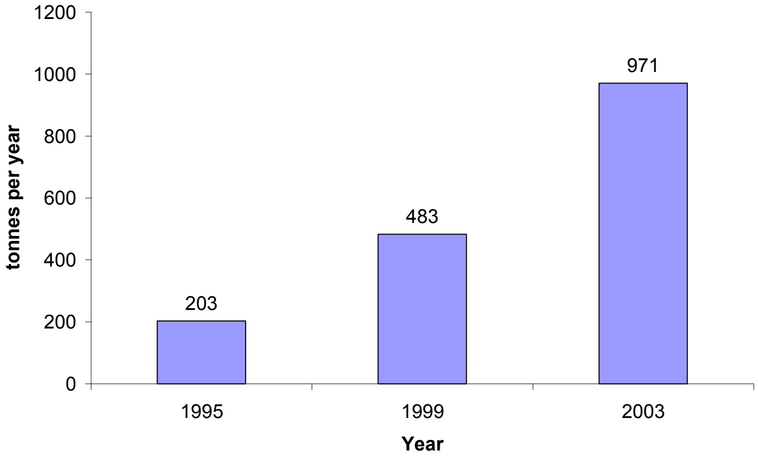


**Figure 6-3. Pesticide use (sum of insecticides, fungicides and herbicides) in Latvia agriculture 1995-2003,** ***tonnes active substance per year.***

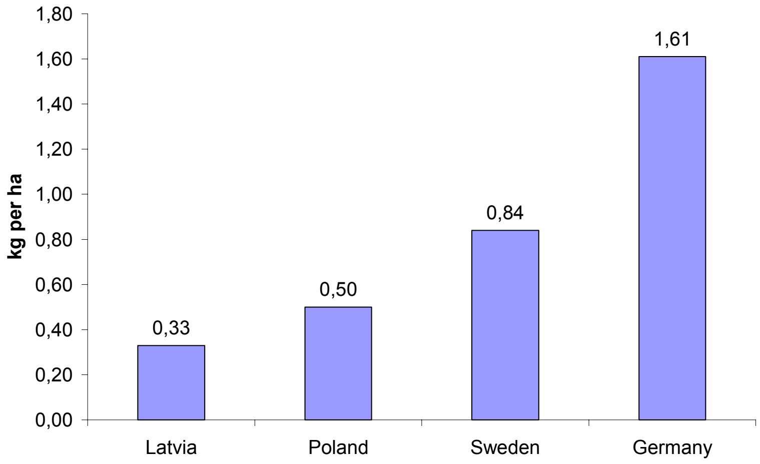


**Figure 6-4. Use of pesticides in four of the eight BERAS countries year 2003, *kg active substance per ha*.**

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# 7. Organic waste management studies

Two different cases of organic waste management systems have been studied in the BERAS project. The most extensive study was performed in Juva, Finland. Following that, a description of a farm-size biogas plant in Järna and a discussion about the possibilities for combined recycling (re-use of nutrients) and energy "production" is presented.

## *Inventory in Juva*

*Tiina Lehto, South Savo Regional Environment Centre, Finland*

The objective in the inventory conducted at Juva is to determine the possibilities for recycling biowaste (organic waste) produced by local food actors back into agriculture. The examined food actors belong to the food chain after primary production (agriculture): food processors, grocery stores, schools, communal kitchens, and private consumers. The research methods used are waste flow and substance flow study.

The study first looked into the current waste management system within the Juva community and among specified food actors. Special attention was focused on biowaste and nutrient flows. Because biowaste recycling into fields in Juva was scarce in 2002, an assessment was made of the possibilities to recycle biowaste back into agriculture.

Recycling of biowaste can recycle nutrients back into agriculture and thereby add humus to agricultural land. In organic agriculture, nitrogen is fixated by plants, but it is estimated that there will be lack of phosphorus in the future. Biowaste could compensate nitrogen fixation and it could be a good source of phosphorus. Legislation sets demands on biowaste recycling and sewage sludge, for example, is not permitted to be used in organic agriculture in Finland. Considering the recycling of food waste and animal-based by-products, it is necessary to take into account regulation (EC) No. 1774/2002, which lays down health rules concerning animal by-products not intended for human consumption. This regulation was enacted mainly because of the BSC epidemic and foot and mouth disease, and it affects and limits the recycling of animal-based by-products, including food waste from kitchens and animal-based biowaste from grocery stores.

### Materials and methods

The system under study is aimed at food actors in the Juva population centre; a few food processors are situated in urban area. Food actors are food processors processing meat, milk, vegetables and cereals, three communal kitchens including schools, three grocery stores, and private households. Also included is the wastewater led to the communal wastewater treatment plant and the sewage sludge thus formed. The research methods used were waste flow and substance flow study. The substance flow study considered especially N and P flows included in the biowaste.

Data for the study was mainly obtained through interviews, enquiries and analyses results (Savolab Oy 2003, Jyväskylän yliopisto, 2005). Also included was an assessment of the amount of biowaste produced by households because is assumed that part of biowaste ends up as landfill waste. The calculated amounts of biowaste produced by households are based on the following assumptions: one person in the region of South Savo produced about 220 kg of waste in 2000 (Angervuori, 2002); about 33% of all household waste in population centres and about 40% of the household waste produced in rural areas is biowaste (Statistics Finland

1994); in the case of the Juva population centre, about 40% of the inhabitants are included in separate biowaste collection, and the rest compost their biowaste on their property (YTI-tutkimuskeskus, 2004); the inhabitants of the rural area of Juva are obligated to compost their biowaste; the yield of biowaste via separate collection is 70% (Rejlers Oy 2000); Juva had a population of 7449 in 2002, and 3628 of them are estimated to live within the population centre (48.7%).

The estimates of the nutrient flows resulting from the biowaste (Table 7-1) are based on the Fineli-Finnish Food consumption Database of the National Public Health Institute (National Public Health Institute, 2005) and the estimates of the nutrients included in household wastewater are based on the estimates presented by Eilersen et al. (Magid et al., 2002). The dry matter content of food products have been estimated based on the feed tables produced by Agronet (2005). Separately collected biowaste is assumed to contain 20 g/kg N and 4 g/kg P in dry matter, which is assumed to correspond to 35 mass-percent (Sokka et al., 2004). Laboratory analyses were made by studying sewage sludge samples from Juva wastewater treatment plant and from compost samples taken from the Juva stack-composting area (Jyväskylän yliopisto, 2005) (Table 7-2) to determine the nutrients that could be recycled at present and to determine whether the heavy metal concentrations are below the limits set by regulations. The analysis results for the incoming wastewater at the treatment plant were already available (Savolab Oy, 2003) (Table 7-1). These data are based on the average daily nutrient concentration of five samples analysed in laboratory conditions. The conversion factor used for biowaste is 0.3 tonnes/$m^3$.

**Table 7-1. The nutrient values used for different kinds of foodstuffs and biowaste.**

| *Waste component* | *N* | *P* | *Dry matter* |
|---|---|---|---|
| Lettuce (g/kg) | 1.76 | 0.4 | 10.3 %[1] |
| Oat husk (g/kg) | 28[2] | 4.3 [2] | 88 % |
| Turkey offal (g/kg) | 35.2 | 1.5 | 35 % |
| Raw milk (g/kg) (Tuhkanen 2005) | 5.2 | 1 | 12 % |
| Organic milk (g/kg) | 4.8 | 0.9 | 12 % |
| Pig carcass (g/kg) | 27.5 | 1.8 | 35 % |
| Separately collected biowaste (g/kg dry matter) | 20 | 4 | 35 % |
| Household wastewater | 14 | 2.2 | 135 |
| - faeces g/cap/day | 1 | 0.5 | 35 |
| - urine g/cap /d | 11 | 1.5 | 60 |
| - kitchen liquid waste g/cap/d | 0.5 | 0.1 | 20 |
| - bathroom, grey water g/cap/d | 1 | 0.3 | 20 |
| Nutrients to treatment plant, kg/d (Savolab Oy 2003) | 60.4 | 12.8 | |
| Nutrients into water systems, kg/d (Savolab Oy 2003) | 49.2 | 0.46 | |

[1] Dry matter of cabbage
[2] Nutrients in oat bran

## Waste system in Juva

Figure 7-1 shows the biowaste flows produced by the various food actors in 2002 and Figure 7-2 presents an assessment of the nutrient flows included in biowaste. The total solid biowaste amount produced by the various food actors was about 1 150 tonnes, containing 27.6 tonnes of N and 1.6 tonnes of P (excluding quill waste). About 214 tonnes were treated in the communal waste management system by stack-composting the waste. The biowaste in the stack-composting area contained about 0.71 tonnes of N and 0.15 tonnes of P. The stack-composted biowaste originated mainly from households and from one vegetable processor; the remainder came from grocery stores in the population centre and from communal kitchens. About 10% of the biowaste originating from grocery stores was estimated to be former animal-based foodstuffs. About 70% of the biowaste produced was transported outside Juva; a large amount went to animal fodder industry, containing as much as 89% N (24.6 tonnes of N) and 66% of P (1.05 tonnes of P) of the total nutrient amount of the biowaste produced by the food actors covered by this study. A smaller amount appears to have ended up in a landfill in Mikkeli (50 km away) along with mixed waste. At maximum 12% of the biowaste was treated at the food actors' own systems in Juva, but the said proportion appears not to have been utilised on fields to benefit food production.

Wastewater led to the Juva waste-water treatment plant is mainly from households. Most significant industrial plants in the area are a diary and a slaughterhouse, adding BOD and nutrient load to the incoming waste water. In addition waste waters of a vegetable processor, a printer house and a fur refinery are led to the waste water treatment plant. The wastewater treatment plant in Juva is a BIOLAK treatment plant built in 1982, which has later been provided with a facility for phosphorus precipitation by iron(II)sulphate. The resultant sewage sludge is subjected to filter-pressing; with polymers being used as aiding agents. In 2002, the incoming wastewater to the treatment plant amounted to 421 000 $m^3$ with a solid matter content of 134 tonnes and containing 22.0 tonnes of N and 4.7 tonnes of P. The amount of iron(II)sulphate used was 80.7 tonnes (Savolab Oy 2003) and the removal efficiency of phosphorous was 96% and that of nitrogen was 19%.

The sewage sludge amount formed in 2002 was 512 $m^3$ (about 364 tonnes[15]) with a dry matter content of 18%. According to analyses results obtained in 2005 (Table 7-2), the sewage sludge contained 4.4% of N and 2.9% of P (in terms of dry matter). According to the removal efficiency in 2002, the sewage sludge contains at maximum 4.1 tonnes of N and 4.5 tonnes of P. Nitrogen can escape from the process through denitrification and evaporation, but phosphorus is believed to be slightly soluble because of phosphorus precipitation. The heavy metal concentrations of the sewage sludge are below the requirements of the relevant regulations imposed on sewage sludge for agricultural use; the exception is chromium. The chromium concentration was much higher than the permitted amount.

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[15] According to analysis made in 2005 volume weight was 771 g/l (Table 7-2).

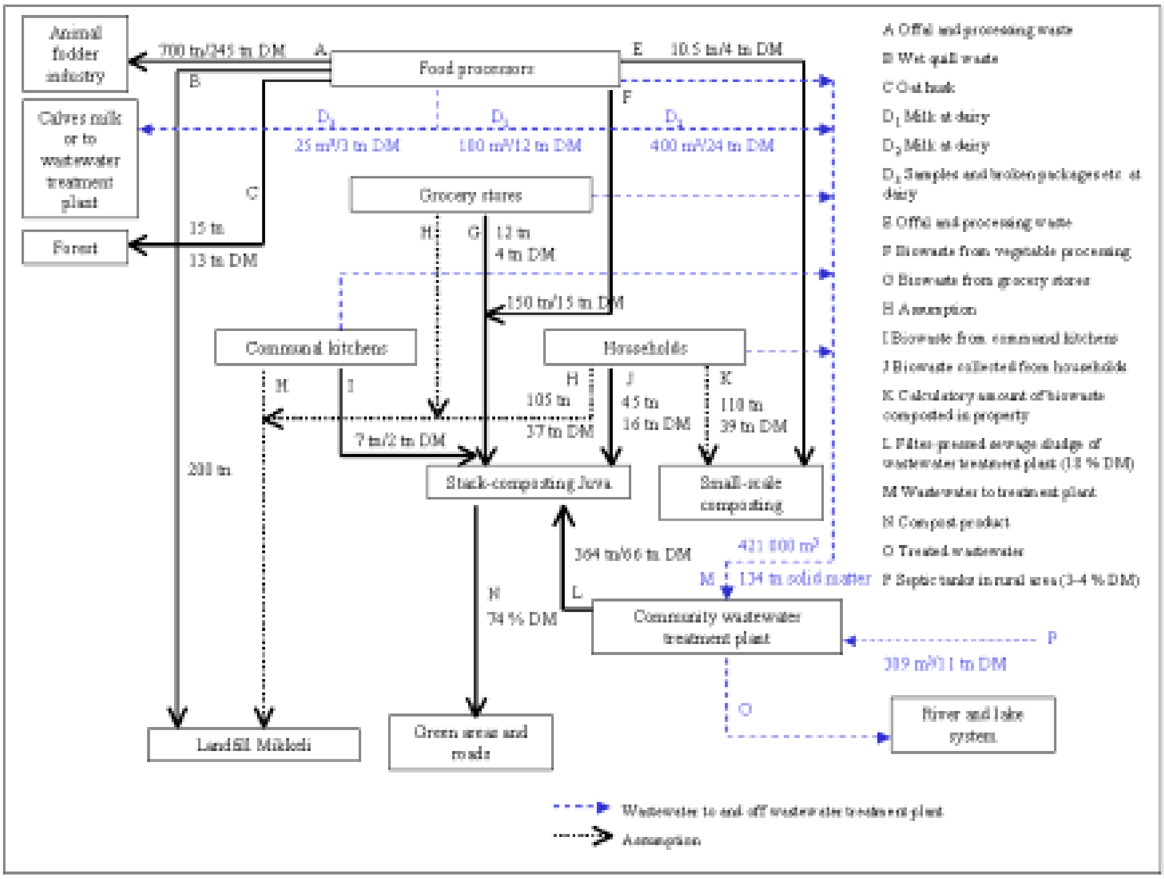

**Figure 7-1. Biowaste flows involving Juva food actors in 2002 (DM = dry matter).**

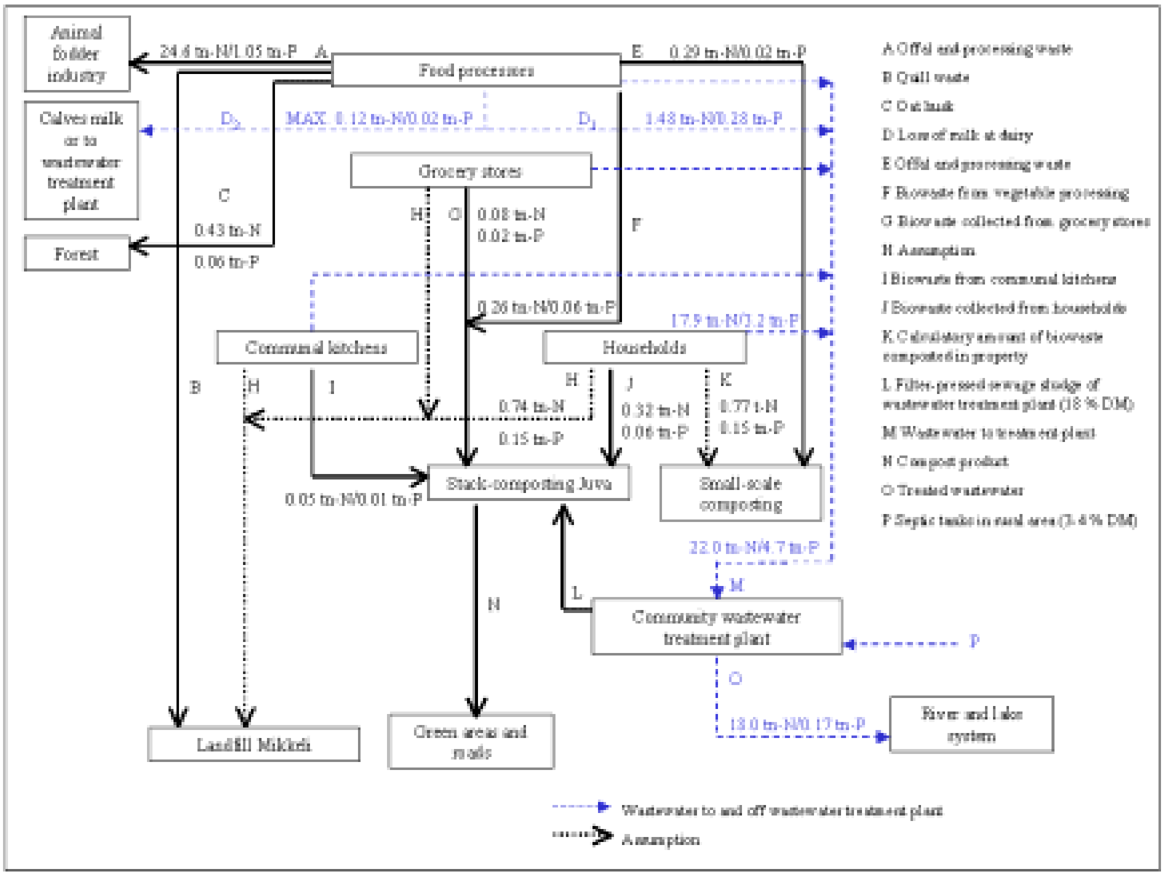

**Figure 7-2. Nutrient flows of biowaste involving Juva food actors in 2002.**

The sewage sludge formed was composted in the communal stack-composting area along with the separately collected biowaste. Tree bark and leaves and gravel were mixed in with the sludge and biowaste being composted to promote the composting process and to produce a final product of better the quality. The nutrient concentrations of the compost as analysed in 2005 were low; 0.28% of N and 0.32% of –P, but the heavy metal concentrations fulfilled the requirements of the regulations. The nutrient concentrations of the biowaste can be assumed to be the same as in 2002, because no noteworthy changes in biowaste flows or treatment have occurred. The organic matter (33%) and dry matter content (74%) of the compost samples indicate that the mineral content is relatively high (Jyväskylän yliopisto, 2005). According to a decision of the Ministry of Agriculture and Forestry (46/1994), the humus content has to be at least 20% of the dry matter content. The compost product has previously been used in green areas and in road construction, and now it is being stored for the purpose of landscaping an old landfill; local farmers have not accepted it.

**Table 7-2. Analyses results for the compost product from the stack-composting area and the sewage sludge from the wastewater treatment plant in Juva (Jyväskylän yliopisto, 2005).**

| *Analysed property* | *Unit* | *Sewage sludge from Juva* | *Vnp*[1] *282/1994* | *MMMp*[2] *46/1994* | *Compost from Juva* |
|---|---|---|---|---|---|
| Volume weight | g/l | 771 | | | 696 |
| Conductivity | mS/m | 30.6 | | | 2.70 |
| pH-value | pH | 6.5 | | | 6.6 |
| Ignition loss | % DM | 65 | | | 33 |
| Dry matter (DM) | % | 18 | | | 74 |
| Total nitrogen | % DM | 4.4 | | | 0.28 |
| Total phosphorus | % DM | 2.9 | | | 0.32 |
| Total potassium | % DM | 0.20 | | | 0.18 |
| Total magnesium | % DM | 0.16 | | | 0.21 |
| Total calcium | % DM | 1.1 | | | 0.28 |
| Mercury | mg/kg DM | 0.24 | 1.0 | 2.0 | 0.07 |
| Cadmium | mg/kg DM | 0.6 | 1.5 | 3.0 | < 0.5 |
| Total chromium | mg/kg DM | 530 | 300 | - | 21 |
| Copper | mg/kg DM | 240 | 600 | 600 | 39 |
| Lead | mg/kg DM | 31 | 100 | 150 | 6 |
| Molybdenum | mg/kg DM | 3 | - | - | < 1 |
| Nickel | mg/kg DM | 20 | 100 | 100 | 7 |
| Sulphur | mg/kg DM | 6 800 | - | - | 520 |
| Zinc | mg/kg DM | 480 | 1 500 | 1 500 | 88 |

DM = dry matter

[1] Decision of the Council of State (Vnp) No 282/1994

[2] Decision of Ministy of Agriculture and Forestry (MMMp) No 46/1994

## Conclusions

In 2002, biowaste composted in stacks could not be recycled back into agriculture at Juva. The treatment process did not fulfil the requirements; especially the by-product directive 1774/2002 as the compost included former animal-based by-products in the form of food waste and former animal-based foodstuffs from grocery stores. The final product could then only be used in landfills (as covering or filling material). If final product is used in agriculture or in greening areas in the future, then the composting treatment has to fulfil the requirements of the by-product directive. Otherwise, the product can be taken only to landfills. Alternatively, it is possible to compost only the biowaste of vegetables and other non-animal-based by-products and sewage sludge.

Alternative treatment processes to recycling of nutrients and humus of biowaste are biogas treatment and composting (centralized or small-scale treatment or co-digestion plant). The treatment of biowaste and wastewater cause nutrient losses and all nutrients in the treated biowaste do not become available to plants. Figure 7-3 shows summarized total nutrient and dry matter percentages of the biowaste produced by food actors, including wastewater to the treatment plant, in Juva in 2002. Most of the nutrient-containing components originated from food producers and from urine. Slaughterhouse waste and food-processing waste contained 52% of N and 19% of P of the total nutrient amount (93% of N and 75% of P of the solid biowaste) and urine contained 29% of N and 32% of P of the total nutrient amount (66% of N and 43% of P of wastewater nutrients). Slaughterhouse waste could be a good nutrient source, but the current regulations pertaining to former animal-based by-products may prevent the recycling of these nutrients back to agricultural land.

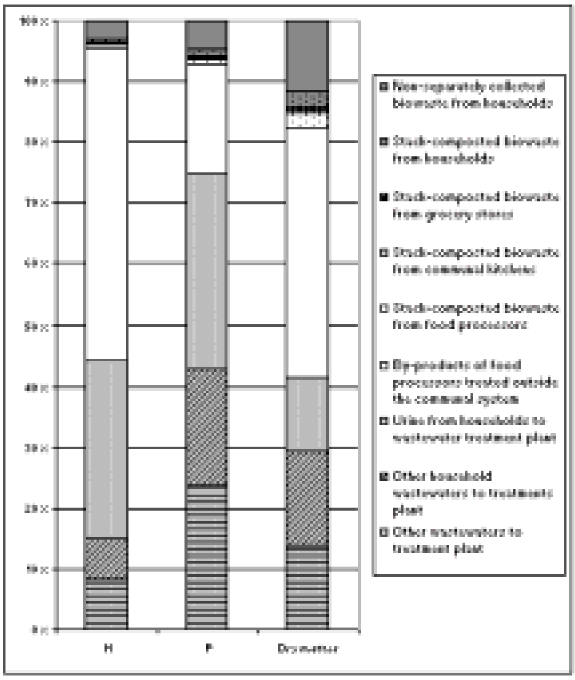

**Figure 7-3. N, P and DM flows of biowaste and wastewater to the treatment plant in 2002, Juva. (Dry matter of wastewater is assumed to be double that of solid matter content.)**

It should be noted that urine contains about 1/3 of the nutrients formed within the studied food system and even a greater share of the nutrients in incoming wastewater flow to wastewater treatment plant in Juva in 2002. From the environmental viewpoint, separate urine collection would be preferable to the conventional system. It would increase the recyclable nutrient amounts to fields and at the same time decrease the emissions into water systems. In addition, phosphorous would be in more usable form for plants and risk of heavy metals would be minor compared to sewage sludge. Because of present technology urine separate collection is not respectable in urban area.

## Biogas plant in Järna

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The Biodynamic Research Institute in Järna developed an on-farm biogas plant integrated within the self-contained farm organism, BERAS-farm Skilleby-Yttereneby. The plant digests manure of dairy cattle and organic residues originating from the farm and the surrounding food processing units containing 17.7-19.6 % total solids. The developed and implemented technique is based on stable manure and food residues on a two-phase process and new technology for continuously filling and discharging the hydrolysis reactor. The output of the hydrolysis reactor is separated into a solid and liquid fraction. The solid fraction is composted. The liquid fraction is further digested in a methane reactor and the effluent used as liquid fertiliser. Initial results show that anaerobic digestion followed by aerobic composting of the solid fraction improves the nutrient balance of the farm compared to mere aerobic composting.

## Methodology

Manure of a dairy stanchion barn with 65 adult bovine units is shifted by a hydraulic powered scraper into the feeder channel of the hydrolysis reactor. The urine is separated in the barn via a perforated scraper floor. The manure is a mixture of faeces, straw and oat husks. From the feeder channel the manure is pressed via a 400 mm wide feeder pipe to the top of the 30° inclined hydrolysis reactor of 53 $m^3$ capacity. The manure mixes itself with the substrate sinking down by gravity force. After a hydraulic retention time of about 22-25 days at 38°C, the substrate is discharged by a bottomless drawer from the lower part of the reactor. Every drawer cycle removes about 100 l substrate from the hydrolysis reactor to be discharged into the transport screw underneath. From the transport screw the substrate partly drops into a down crossing extruder screw where it is separated into solid and liquid fractions. The remaining material is conveyed back to the feeder channel and inoculated into the fresh manure. The solid fraction from the extruder screw is stored at the dung yard for composting. The liquid fraction is collected into a buffer and from there pumped into the methane reactor with 17.6 $m^3$ capacity. Liquid from the buffer and from the methane reactor partly returns into the feeder pipe to improve the flow ability. After a hydraulic retention time of 19-21 days at 38°C the effluent is pumped into a slurry store covered by a floating canvas. The gas generated by both reactors is stored in a sack and fed by a compressor to the process heater and the furnace of the estate for heating purposes (Schäfer, 2003).

## Results

The results concerning the nutrient contents are presented in more detail in a separate on BERAS homepage available manuscript (Schäfer et al, 2005).

During the anaerobic digestion in process A, 14.6-15.4 % of carbon was found in the biogas. During aerobic composting, 26-31 % of the input carbon of the solid fraction escaped. In process B 58-60 % of the carbon escaped during aerobic composting. Even if the biogas yield would be threefold more, there would still be 41-42.5 % carbon available for composting of the solid fraction. This confirms the hypothesis that biogas production before composting hardly has a negative impact on the humus balance (Möller, 2002) compared to mere aerobic composting.

Total nitrogen losses ranged between 30% and 48% in process B and between 19% and 29% in process A. Similar values we found for $NH_4$: up to 6% losses in process A versus 96% in process B. Potassium and phosphorus losses were higher in process A than process B. The results confirm the calculations of Möller (2002) that biogas production increases recycling of $NH_4$ and reduces overall nitrogen losses compared to mere aerobic composting.

## Conclusions

The two phase prototype biogas plant in Järna is suitable for digestion of organic residues of the farm and the surrounding food processing units. The prototype put many recent research results into practice. But there is still a lack of appropriate technical solutions in terms of handling organic material of high dry matter content, and process optimisation. The innovative continuously feeding and discharging technique is appropriate for the consistency and the dry matter content of the organic residues of the farm. It is probably not suitable for larger quantities of un-chopped straw or green cut.

Anaerobic digestion of manure and organic residues followed by composting the dry fraction of the hydrolysis reactor improves the energy and nutrient balance on-farm compared to mere aerobic composting. Appropriate new technical design as used at the prototype biogas plant in Järna is a key factor.

To confirm the present results more measurements are necessary. The optimisation of the plant in respect of hydraulic retention time and load rate may lead to higher gas generation but requires an improved measuring technique. Thereafter an economic evaluation is necessary to assess the competitiveness of the new technology. The benefit of an on-farm biogas plant may be considered in a larger extent if we include into the nutrient balance not only the biogas plant but also the nutrient circle of a whole crop rotation period of the farm organism. The quality of the nutrients is finally related to soil fertility, fodder quality and animal health.

## *Possibilities for developed recycling and renewable energy production in Juva and Järna*

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The plant nutrients in food stuffs from agriculture end up in slaughterhouse wastes, domestic wastes (wastes from household and food industry) and sewage wastes. These three fractions contain 4, 3 and 2 kg N per capita and year and 2, 0.5 and 1 kg P per capita and year calculated from Magid et al. (2002). About 60 percent of the nitrogen and 45 % of the phosphorus belonged to the liquid wastes residues manly in the human urine fraction. Of the total phosphorus taken up by plants (20 kg P per ha) about 75 % can be recycled within the farming system on ERA farms with an optimal utilization of the recycled nutrients in manure. But 15 % is found in the sewage fraction from the human consumption and could be re-circulated to the agriculture through urine separation if also the hygienisation can be realised on a secure way. Another 10 % is found in the slaughter wastes which also in an important resource for the sustainable agriculture.

Two ways of local recycling of the solid fraction of biomass combined with producing biogas are presented within the BERAS-project. The goal is safe recycling of nutrients, reduced emissions of greenhouse gases and reduced emissions of reactive nitrogen. One way is the central recycling on commune level with production of biogas described above for Juva. However, the central biowaste treatment raise problems with the quality control and with high risk for contamination of heavy metals, medicaments, and animal and human pathogens, implying that these nutrients can not be used on soil for food production.

The second option is to have a more small-scale system with better opportunities to choose and control the material treated. An example of this is the recycling of food residues introduced in the small-scale biogas plant on Yttereneby in Järna described above. This local small-scale biogas plant on farm level could be argued to be a better solution for recycling of nutrients from human food (local processors, ecological public kitchens and consumers) since it gives opportunities to have a good control against contaminations of pathogens and harmful substances. This was established as an essential link in the local ecological recycling system that at the same time reduce emissions of greenhouse gases. Only food residues from the ecological farms, ecological small scale food processors and ecological consumers are used. Permission for this local recycling was obtained from the commune. The biowaste is hygienised by one hour heating in 70 $^0$C with help of the energy from the biogas plant. For the farmer, the recycled nutrients from the food chain combined with the treated manure from the farm become a trustworthy and valuable resource. A further step would be to also use slaughter wastes from a more local slaughterhouse, when/if that will be built according to plans in Järna. Receiving selected biowastes from outside the farm also seems to improve the mixture of input material, which increases the biogas production. Gate fees would bring incomes to farmers.

On-farm biogas plant treatment in Juva would also support the agriculture and a preliminary design for a biogas plant in Juva was developed in 1997 (Citec Environmental Technology, 1997). There were nine food actors, waste producers and users of hydrolysis residual included in that design. In addition to biogas-plant treatment, a controlled way to treat biowastes near origin place could be drum-composting of e.g. biowastes from food processing.

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# 8. Consumer surveys in Juva and Järna for identification of eco-local food baskets

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## *Introduction*

Our food habits are, unquestionably, important both for our own health and for the health of the environment. This is recognised as one of the starting points in BERAS. This is also one of the key issues of the S.M.A.R.T. recommendations (CTN 2001). The consumer survey presented here was aimed to provide information about the food habits of environmentally concerned residents in two of the BERAS case study sites. The aim was that this information be used as input for comparisons to Swedish and Finnish average food baskets to determine their respective environmental impacts in the whole food system, reported in other chapters in this report.

The consumer surveys put together realistic food baskets (consumption profiles) for a Swedish and a Finnish case, containing mainly locally and ecologically produced foodstuffs. The unit used is kg food in different product groups per capita and year. Economic results as € per capita for different household types and year are reported in short here, and in more detail in other BERAS reports (Sumelius, 2005).

### Case study sites

The case studies were carried out in Juva, Finland and Järna, Sweden – the same sites used for many other studies in the BERAS project. Both the municipality of Juva and the community of Järna have around 7500 inhabitants. For a more detailed presentation of the sites see Seppänen (ed. 2004).

Juva is a rural municipality in South-Savo region, about 270 km northeast of Helsinki. Compared to neighbouring areas, Juva has a strong tradition of organic farming. In Juva 15.8 % of the cultivated land is organic, compared to Finnish average 7.6 %. Compared to many other rural municipalities Juva has a strong food processing industry,  comprising a dairy, a flourmill, vegetable processing enterprises, meat processing enterprises and bakeries. The dairy processes organic milk while the other enterprises use conventional, non-organic, raw-products.

The small town of Järna is part of Södertälje municipality, located in Stockholm County, 60 km south of Stockholm. The heart of the case study lies in the outskirts of Järna and is connected to an anthroposophist community with a high concentration of anthroposophist initiatives and small businesses which prefer to use biodynamic and organic products. There are several biodynamic farms and market gardens in the area that serve the local market and a well developed consumer network linked to these farms. There are also several food processing industries like a mill and bakery (with both a local and nation market), a farm-size dairy and a farmer cooperative selling vegetables and meat.

### Subjects

Most of the research subjects in the study are individuals or families devoted to environment and health, living in Juva, Finland and in Järna, Sweden (Table 8-1). The families were invited to take part in the survey through local food and environment organisations and through staff in the local ecological farming research institutes.

**Table 8-1. Composition of research subjects.**

| | Juva | | Järna | |
|---|---|---|---|---|
| period | April 2004 | October 2004 | February 2004 | September 2004 |
| no. households | 9 | 9 | 15 | 13 |
| no. adults | 15 | 15 | 29.5 | 25 |
| no. children 0-19 years | 13 | 12 | 19.5 | 18.5 |

## Methodology

The methodology used for the data collection differed slightly between the two case studies but, basically, the families recorded their food purchases for two two-week periods; one in winter/spring (when local products are scarce) and one in late summer/early autumn (when local products are easy available). The periods were chosen in order to get representative results for the yearly consumption. In Finland, the first period was performed during April 2004 and the second in September and November 2004. In Sweden, the survey started in February 2004. The second survey was made in September and early October.

In both Finland and Sweden a family member collected the receipts or filled in purchase diaries for all food entering the household for human consumption during the 14 days period. Information on the amount, price, origin and environmental brand of all food products was recorded either on the detailed receipts or on the specified lists supplied by the project.

After the recording period, the families were interviewed about their food choices, food consumption and food purchasing habits. In the interviews, information on the quantities of different kinds of food that were brought into or taken out of the household stores and the quantities of home-produced food was collected, to get representative values for the consumption during a two-week period at that time of the year.

The amounts of different products purchased during the measured four weeks were then extrapolated to get values for consumption during the whole-year. The comparable data for Finnish average food consumption were obtained from Tennilä (2000) and for the Swedish average from Jordbruksverket (2004).

For some comparisons to Swedish average figures, the results for the Järna consumers were also extrapolated to cover meals eaten outside the home based on an estimated factor. The factor was obtained through an estimation made by each household of how many meals they ate outside the home in an average week during the measuring periods, and an assumption that each person eats three meals a day. In average, the Järna households ate 16 % of their meals outside the home. Thus, when measured consumption was compensated for "eating-out" the original figures were multiplied by 1.16. This implies an assumption that food eaten outside the home had the same proportions of different product groups and energy content as that purchased for home-consumption. In the Juva study, meals eaten outside were not taken into consideration because the Finnish statistics only cover the expenses for food which is bought and eaten at home.

The method used in this consumer survey has some limitations which should be taken into account when interpreting the results. The purchase diary used in these studies records food availability in households, not the food consumption of individual people. In other words, the results presented here per capita per year are estimations about purchased food, not actual food consumption. Also, purchasing patterns may be distorted and no information on the distribution of foods within households is normally obtained (Cameron, 1988). One problem is the possible lack of information about whether a product is never purchased or whether it simply was not purchased during the recorded weeks (Irish, 1982). Bulk purchases make it more difficult to estimate annual food expenditures than if the consumers acquire all or part of their food in relatively small quantities once or several times per week (Pena, 1998). However, when the families were interviewed and their purchase diaries and collected receipts checked, information on the above issues was received.

## *Results and discussion*

The results for amounts of different food products consumed are presented and discussed separately for the two surveys and compared to the national averages respectively. The shares of ecologically and locally produced foods and the expenditures for food are presented and discussed in the following sub-chapters.

### Amounts of food consumed in the Juva households

The main differences in the consumption patterns between the investigated households in Juva and the Finnish national average are the lower consumption of meat and potatoes and the higher consumption of garden products (Figure 8-1). However, concerning the potatoes and garden products it is only possible to comment on the *purchased* amount. Some families grow their own potatoes and vegetables, and as this has not been taken into account in the results, the consumption may be substantially higher than the results indicate. On the other hand, there were some bulk purchases of carrots. One vegetarian and one meat producer may account for lower meat consumption. Thus the difference in consumption patterns may partly be explained by weaknesses in the methodology. Other differences are small when looking at whole product groups.

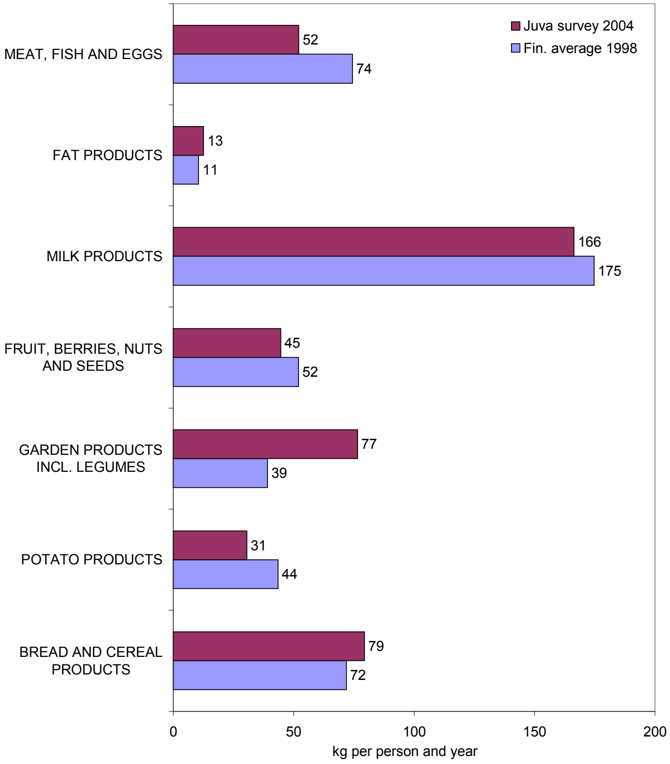

**Figure 8-1. Food consumption of product groups in Finland 1998 and in the Juva survey 2004. Meals outside home excluded.** *kg per person and year*

When the product groups are broken down into smaller groups (Figure 8-2) additional differences, but no striking new patterns, appear.

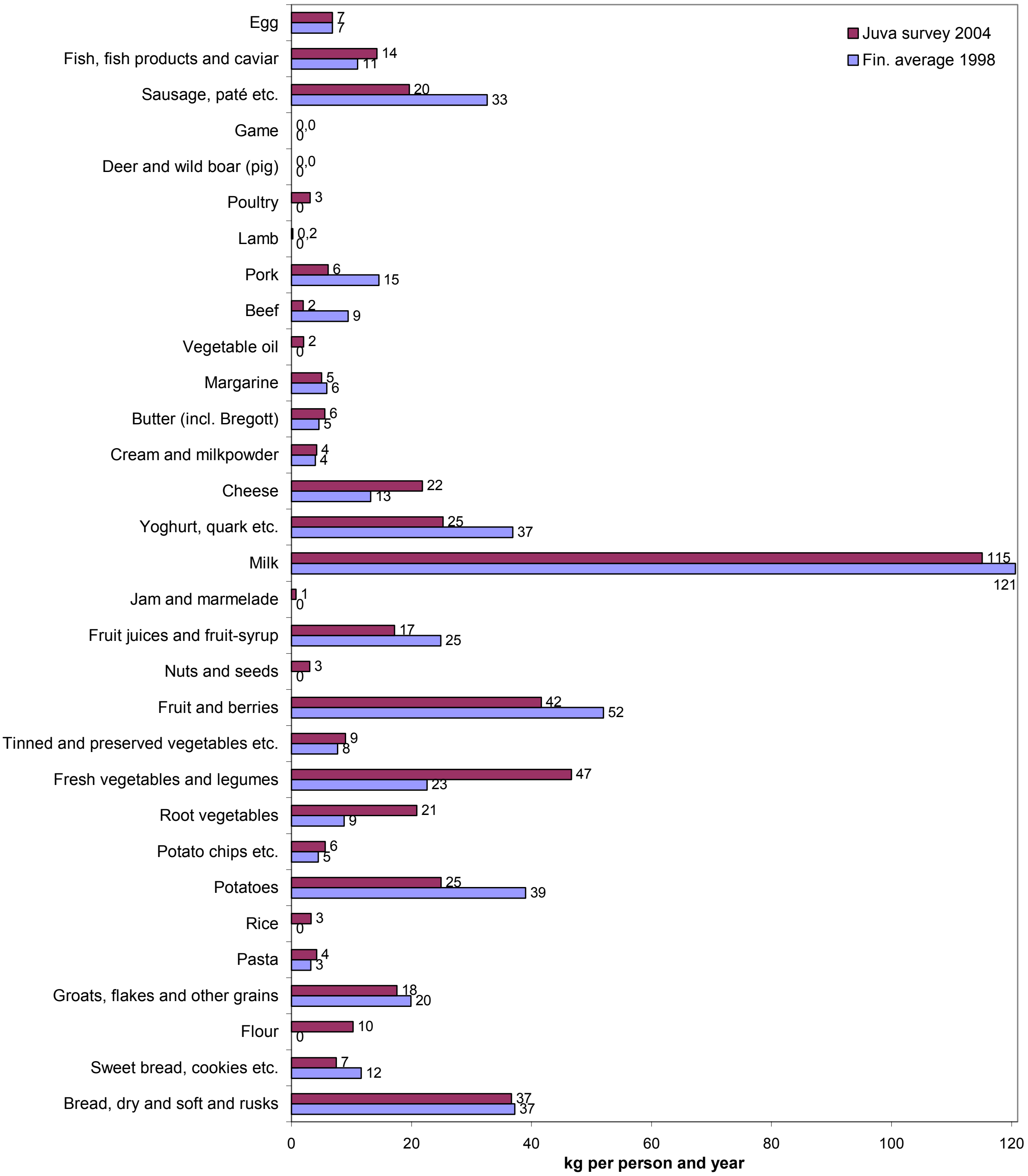

**Figure 8-2. Food consumption of detailed product groups in Finland 1998 and in the Juva survey 2004.**
*kg per person and year*

## Amounts of food consumed in the Järna households

When studying the results from the Järna survey there are some evident differences between the consumption patterns in the investigated households and the Swedish average (Figure 8-3). The most obvious are their lower consumption of meat and potatoes and the higher vegetable consumption. The differences in meat and vegetable consumption were expected but that potatoes seem to be less favoured by these households was somewhat surprising. This fact might partly be explained by anthroposophist nutritional concepts recommending limited intake of solanin producing products, like potatoes and tomatoes. Thus, it is likely that the result reflect an actual lower consumption of potatoes.

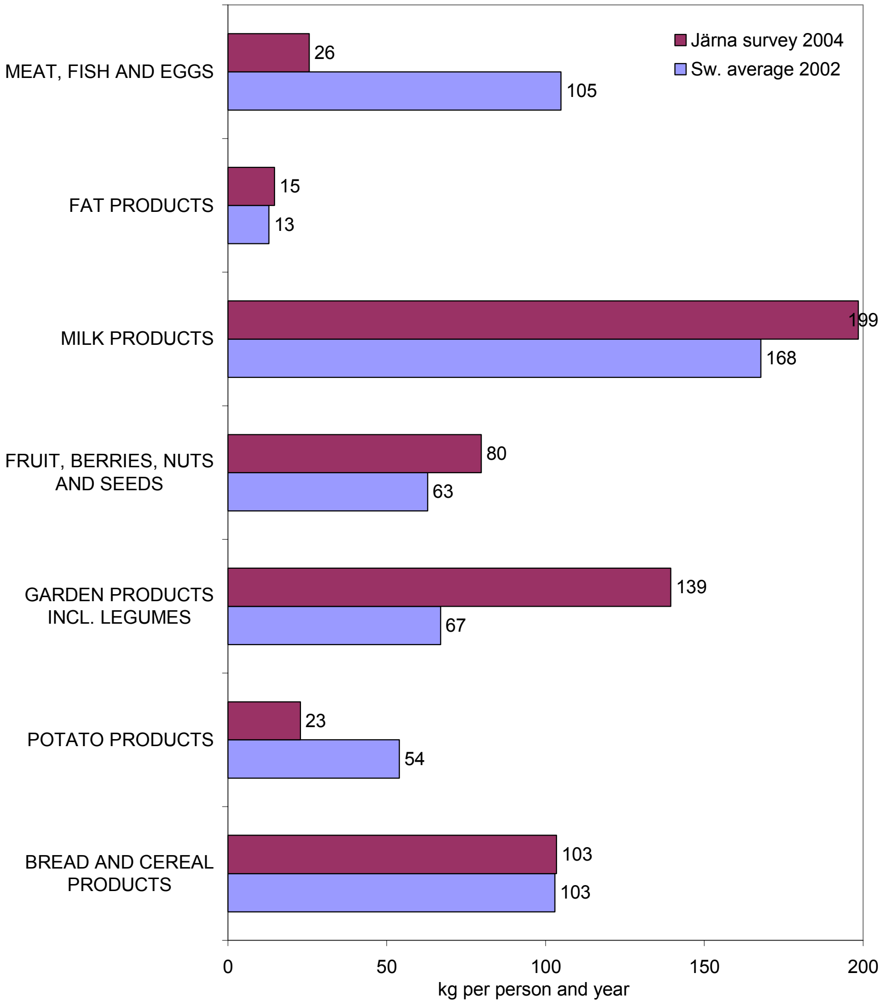

**Figure 8-3. Food consumption by product groups in the Järna survey 2004 and in Sweden 2002. Swedish averages include all meals. Järna figures are corrected for meals eaten outside the home by adding 16 % to purchased amounts.** *kg per person and year*

When looking at more detailed product groups some more interesting differences become apparent (Figure 8-4). Although there is no difference in cereal products as a group it can easily be seen that these households seem to bake more of their bread at home. They also eat more groats and flakes, which is in accordance with the higher consumption of yoghurt and other fermented dairy products. Concerning the fat products consumed, it is obvious that these households prefer butter to the more processed margarine. Figure 8-4 also shows that when these households eat meat, they seem to choose meat from animals that have been kept outside (e.g. lamb and wild boar) in what can presumed to be a more animal friendly production.

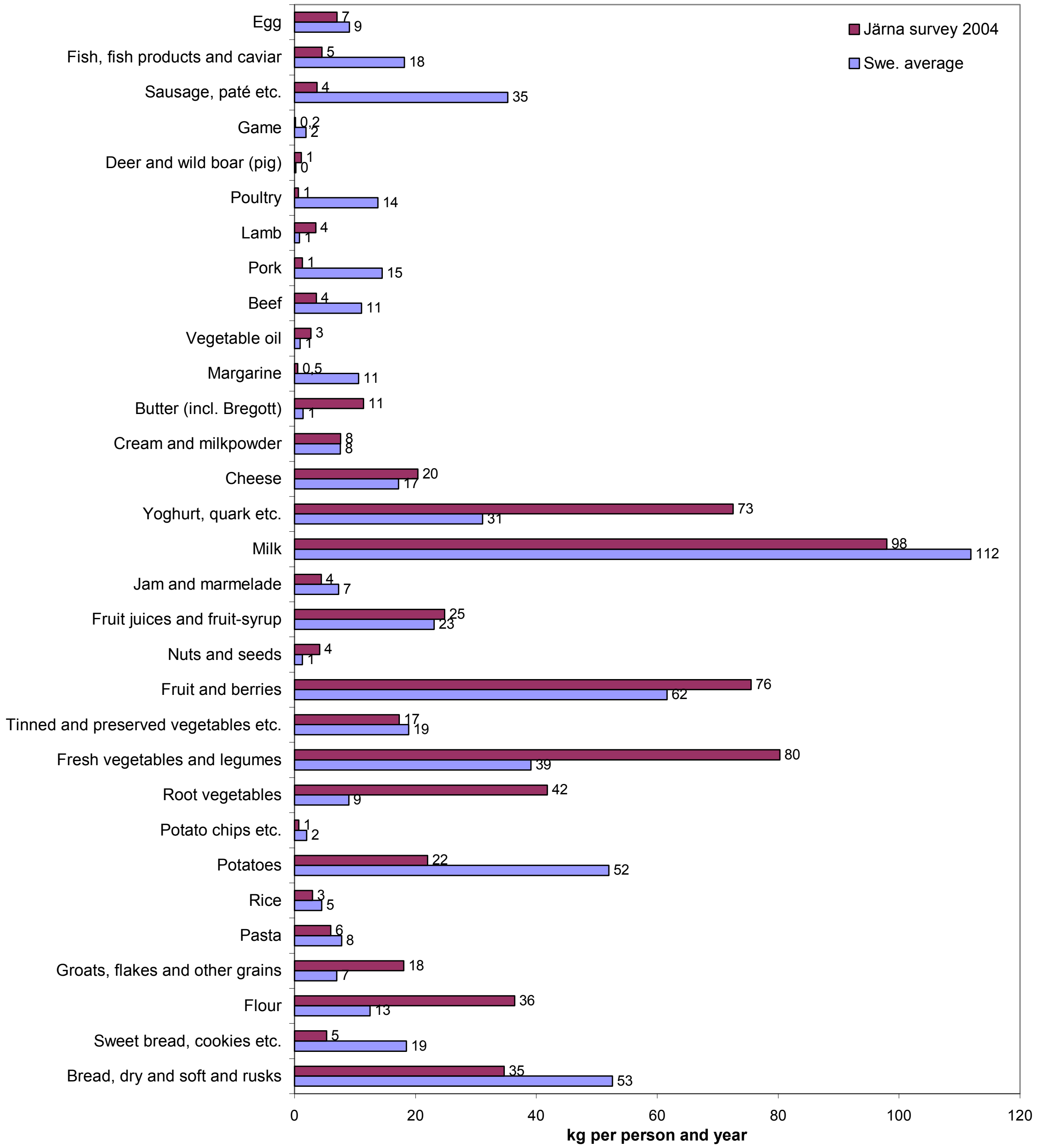

**Figure 8-4. Food consumption of detailed product groups in the Järna survey 2004 and in Sweden 2002. Swedish averages include all meals. Järna figures are corrected for meals outside home – purchased amounts added by the part of meals eaten outside home (16%).** *kg per person and year*

## Share of ecological and local food

The main objective of this study was to present data for an “eco-local” food basket; i.e. a food basket mainly consisting of ecologically and locally produced food. The shares of ecologically and locally produced food reported in the surveys and for national averages are presented in Table 8-2. The households in both Järna and Juva bought a much larger share of ecological food compared to the national averages. The portion of ecologically produced food purchased was substantial for some product groups, especially in Järna.

In Juva the share of ecological food in general was smaller than in Järna but the availability of such products was most certainly a large constraint. For example, no ecological meat or fish was bought in Juva. The reason given was that there very rarely are ecological alternatives on sale. However, the Juva households bought much more ecological milk than average Finns do. Also the share of ecological fresh garden products, cereal products and eggs was larger. In the food basked of the average Finnish consumer, the share of organic food is 1 %. (Tennilä, 2000) In another survey only 4 % of the Finnish households estimated that the share of organic products in their food basket is 6 % or more (Nielsen, 2004). In Finland about 20 % of the consumers answered in interviews that they buy organic products continuously. Half on them have estimated that the share of organic products in their food basket is less than 20 %. (http://www.finfood.fi)

It is worth noting that the share of ecological food in the Järna households is very large, 73 % of the weight for what is considered ‘real food’ (sugar, candy, beverages etc. not included). This is certainly influenced by the availability of these products which in turn is influenced by the long standing demand for ecologically produced food in Järna. Some of the Järna consumers even mentioned that they would have bought more eco-food if it was available and not too expensive.

Concerning the second important issue investigated in BERAS, the locally produced food, the portion purchased by the investigated households was found to be substantial for some product groups (Table 8-2). Also here the shares in general were larger in Järna, again probably the result of there being so readily available. In Juva the share of local food varied greatly between the food groups. For example the share of local milk was 37 % of the weight. This is possible because there is a local dairy in Juva. The share of local cereal products was only 10 % of weight despite the fact that there is a local mill.  The people in the Finnish study seem to prefer the ecological cereal products to the local ones. However, about 20% of the bread purchased is produced by the Juva bakery.

It is not possible to make comparisons with national averages concerning local food. However one can assume that the average share is very low because food retail chains tend to market a nationally standardised assortment favouring centralised suppliers.

**Table 8-2. The share of ecological (organic) and local food purchases in Sweden, in 15 Järna households, in Finland and in 10 Juva households.** *kg per capita and year, and % of weight*

| Product group | Sweden average | | Järna survey 2004[1] | | | | | Finland average | | Juva survey 2004[2] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | total[3] | eco[4] | total | eco | | eco-local[5] | | total[6] | eco | total | eco | | local[7] | | eco-local | |
| | *kg* | *%*[8] | *kg* | *kg* | *%* | *kg* | *%* | *kg* | *%* | *kg* | *kg* | *%* | *kg* | *%* | *kg* | *%* |
| Cereal products | 103 | 1.6 | 103 | 81 | 78 | 58 | 56 | 72 | 3.4 | 79 | 13 | 17 | 8 | 10 | 4 | 5 |
| Potatoes | 54 | 3.3 | 23 | 22 | 96 | 9 | 38 | 44 | 2.7 | 31 | 7 | 24 | 8 | 25 | 4 | 13 |
| Root crops | 9 | 9.9 | 42 | 39 | 92 | 17 | 40 | 9 | 3.5[9] | 21 | 18 | 87 | 16 | 79 | 16 | 75 |
| Vegetables, veg. products and legumes | 58 | 2.0 | 98 | 64 | 66 | 29 | 30 | 30 | 3.9 | 56 | 11 | 20 | 12 | 21 | 5 | 9 |
| Milk products | 168 | 5.1 | 199 | 162 | 81 | 72 | 36 | 175 | 1.8 | 166 | 78 | 47 | 50 | 30 | 50 | 30 |
| Meat ruminants (beef and lamb) | 12 | | 7 | 5 | 70 | 4 | 49 | 9 | * | 2 | 0 | 0 | 2 | 100 | 0 | 0 |
| Meat monogastrics (pork and poultry) | 28 | 0.8[10] | 2 | 1 | 48 | 1 | 28 | 15 | * | 9 | 0 | 0 | 3 | 32 | 0 | 0 |
| Other meat and mixed meat products | 37 | | 5 | 3 | 62 | 2 | 41 | 33 | * | 20 | 1 | 4 | 1 | 7 | 0 | 0 |
| Egg | 9 | 9.7 | 7 | 6 | 88 | 2 | 22 | 7 | 2.1 | 7 | 1 | 9 | 2 | 28 | 0 | 0 |
| Fish and fish products | 18 | 0[11] | 5 | 0 | 3 | 0 | 0 | 11 | 0[11] | 14 | 0 | 0 | 1 | 5 | 0 | 0 |
| Fat | 13 | 2.7 | 15 | 6 | 42 | 0 | 0 | 11 | 3.3[12] | 13 | 1 | 5 | 0 | 0 | 0 | 0 |
| Fruit, berries, nuts and seeds | 63 | 2.6 | 80 | 39 | 48 | 2 | 3 | 52[13] | * | 45 | 1 | 3 | 0 | 0 | 0 | 0 |
| **Total 'real food'**, excl. sugar, candy, beverages etc. | 572 | 2.2 | 584 | 428 | 73 | 194 | 33 | 466 | 1[14] | 462 | 131 | 28 | 103 | 22 | 79 | 17 |

## Households' expenditure on food

The expenditures on food are summarised in Table 8-3 and discussed shortly below. For more detailed results, see BERAS report 3 (Sumelius, 2005).

**Table 8-3. Expenditures on food.**

| | €/CU[15] | €/person/year | €/household/year |
|---|---|---|---|
| Juva | 2213 | 1642 | 4334 |
| Finnish average | no reference | 1580 | 3397 |
| Järna | 2584 | 1800 | 5833 |
| Swedish average | 2084 | 1600 | 3376 |

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[1] compensated for meals eaten outside home
[2] not compensated for meals eaten outside home
[3] Swedish average 2002 (Jordbruksverket, 2004)
[4] certified KRAV, Luomu and/or Demeter
[5] produced in Järna district and, since all local is eco in Järna, certified KRAV and/or Demeter
[6] Finnish average 1998 (Tennilä 2000)
[7] produced in Juva district
[8] % of expenditures per product group
[9] carrots (Finfood Luomu / A.C.Nielsen ScanTrack)
[10] % of all meat and meat products
[11] not possible to certify at that time
[12] oil (Finfood Luomu / A.C.Nielsen ScanTrack)
[13] fruit and berries only
[14] % for all foods
[15] CU = Consumption Unit, a measure that compensates for household structure and the ages of the household members to allow for more relevant comparisons of consumption between different household types.

The Juva households’ expenditure for food was between 1622 and 6815 €/household/year and the mean was 4334 €/household/year. The average Juva household consisted of 2.9 persons. Average consumption expenditure of households in Finland in the year 2001 was 3397 €/household/year for food and non-alcoholic beverages. The value of home grown products is not taken into account in these statistics. The mean Finnish household had 2.15 persons in year 2001 (Statistical Yearbook, 2004).

The Juva households’ expenditure for food per consumption unit (CU) ranged between 908 and 4803 €/CU/year, the mean was 3013 €/CU/year. There is no reference for € per CU in Finland. In Juva average expenditures for food was a little bit higher than the Finnish averages. One reason for this may be that the second purchase diary period was near Christmas and families bought dried fruits etc. for baking Christmas cakes and ginger biscuits in advance.

In Järna the investigated households seem to spend more money on food than the average Swedish household. The mean value for food expenditures per household was 5833 €/household/year in the monitored households, while the Swedish average household expenditures was 3376 €, alcoholic beverages and restaurant meals not counted (Statistics Sweden, 2004). However, when calculated per consumption unit (CU) the difference is smaller. The results was 2600 €/CU/year in Järna compared to 2100 € for the Swedish average CU, a 24 % larger expenditure on food for the Järna households compared to the Swedish average. Whether this is a result of these families really giving higher prioritising to food or of something else is however hard to say. Of course ecological food is generally more expensive but the difference could as well be a result of the socio-economic status of the studied households. This was not investigated in Järna. In the Finnish case the proportion of meals eaten at home was not investigated which might affect the results.

## Reliability of data

Based on the information in the purchase diary the amount of energy consumed was 11.5 MJ/person/day in the Juva district. According to the FINDIET 2002, dietary energy intake was 9.2 MJ/day among men and 6.6 MJ/day among women. For the Järna case, the energy content of consumed (purchased + restaurant meals) ‘real’ food (excl. sugar, sweets, beverages etc.) was 10.7 MJ/person/day, while the Swedish average 2002 was 10.2 MJ/person/day. Thus, we can conclude that our results are in a reasonable range concerning energy content of the purchased food. However, the results are not easily comparable to statistical data due to differences in survey methods.

## Environmental impacts and nutrition recommendations

Our food choices have an effect on the environment. For example what we eat influences the energy consumed during different stages of the food chain. About 15-20 % of the energy consumed is for the transportation of food. (SwEPA, 1997)

Generally one can say that meat is the most energy demanding food to produce and increased meat consumption is problematic. It is also shown in Chapter 5 that local food production and consumption may have environmental gains due to less transportation. Growing field vegetables demand less energy than greenhouse production. Thus, a higher consumption of local and seasonal vegetables, root crops, fruits and berries decreases the energy needed for food transportation.

New Nordic Nutrition Recommendations (NNR) were approved in August 2004. These are guidelines for the nutritional composition of a healthy diet (NNR, 2004). The NNR does not include instructions for sustainable food choices but such recommendations are available at least in Sweden and in Germany (CTN 2001, SwEPA 1997, SwEPA 1998, SwEPA 2000).

In Table 8-4 both nutrition and sustainable food choice recommendations are presented and used to evaluate households' food choices.

**Table 8-4. Examples of recommendations**

| | Healthy nutrition | Environmental perspective Sustainable food choices |
|---|---|---|
| Fruit, berries and vegetables | - A high and varied consumption of fruit and vegetables is desirable | - A high and varied consumption of domestic vegetables, fruits and berries in season and foodstuffs grown in the field.<br>- If needed off-season, imported fruits or vegetables grown in the field, giving preference to products grown in a nearby country |
| Legumes | | - More leguminous plants instead of meat |
| Potatoes | - Traditional use, several nutrients, potatoes have a place in a diet | |
| Cereals | - An increased consumption of wholegrain cereals is desirable | |
| Fish | - Regular consumption of fish | |
| Milk and milk products | - Regular consumption of milk and milk products, mainly low fat products are recommended as a part of balanced diet | |
| Meat | - Consumption of moderate amounts of meat, preferably lean cuts, is recommended as part of a balanced and varied diet | - Less meat<br>- Choose meat from animals that have grazed on natural pasture, e.g. cattle and lamb.<br>- Eat less chicken and pork. |
| Edible fats | - Soft or fluid vegetable fats, low in saturated and trans fatty acids, should primarily be chosen | - Butter instead of margarine |
| Energy-dense and sugar-rich foods | - Food rich in fat and/or refined sugars, such as soft drinks, sweets, snacks and sweet bakery products should be decreased | - Eat less |
| General | | - More locally produced food when this is more eco-efficient.<br>- Ecological food<br>- Eat less foodstuffs which include few nutrients, for example: eat fruits instead of sweets<br>- More easily transported foods, eg. juice as concentrate instead of ready to drink.<br>- Choose the product produced most nearby when there are equal products. |

The food consumption profile of the Järna households seems to follow the diets suggested in the Nordic Nutrition Recommendations (NNR, 2004) and in the S.M.A.R.T. project (CTN, 2004). These households buy a larger share of vegetables (less meat), less ‘empty’ calories, more ecological food, the ‘right’ vegetables (e.g. more legumes and root crops, and less lettuce and cucumbers) and less transported food, compared to the national average food. The only large difference between the results of the Järna survey and the S.M.A.R.T. recommendations is the share of potatoes. The Järna consumers eat substantially less potatoes than the average Swede, while the S.M.A.R.T. project recommends more potatoes. One reason might be recommendations in the anthroposophist nutrient concept to minimise intake of solanin producing products like potatoes and tomatoes.

## Conclusions

We conclude that the consumption profile of the participating households in Sweden differed more from the average Swedish consumers than was the case in the Finish study. However, also the Finnish households participating in this study bought more organic products than ordinary Finnish households. Substantial parts of the food consumed were locally produced but it has not been possible to make any comparisons with national averages due to lack of data.

The calculated expenditures on food in the Finish group were almost the same as the national average. The Järna group spent around 20 % more money on food compared to average Swedish consumers.

The Swedish consumption profile obtained in the study is well suited for use as a good example in the scenario studies of the whole food system reported in the following chapter.

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# 9. Food basket scenarios

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In order to relate the environmental studies presented earlier in this report to food consumption, two scenario studies were performed; one in Järna and one in Juva. The studies differed considerably.

The Järna study covered a large part of the Swedish food basket (food consumption) and compared environmental impacts of the average Swedish food consumption and an 'eco-local' food consumption produced in different food systems. Three dimensions of food systems were explored: food production (ecological recycling agriculture vs. conventional agriculture), processing/transport (local small-scale processing/transports vs. conventional large-scale processing/transports) and type of food consumed (an average food basket vs. a more vegetarian food basket).

The Juva study covered about 50 % of the average Finnish food basket (reflecting the food production in Juva today) and compared the environmental impacts when these foodstuffs are produced by average Finnish agriculture and by BERAS-farms.

## *Food basket scenario, Järna Sweden*

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The eco-local food baskets presented in Chapter 8 represent food consumption profiles consisting of more ecological and locally produced food than is usually the case in the Nordic countries. The Swedish case also represents a consumption profile that consists of less meat and more vegetables and root crops, which is more in accordance with nutritional and environmental recommendations given in, for example, the S.M.A.R.T. material (CTN, 2001).

The aim of this study was to investigate if, and by how much, the environmental impacts could be reduced by various changes in the food system. The three main research questions were:

1. What is the environmental impact of food produced on ERA (ecological recycling agriculture) farms compared to food from conventional agriculture?
2. What is the environmental impact of food produced and processed locally compared to average food that to a large extent is produced and processed far away in large-scale industries?
3. What is the environmental impact of the alternative food consumption profile obtained in the consumer survey in Järna compared to the average Swedish food basket?

### Methodology

The environmental impacts assessed were nitrogen surplus in agriculture, and global warming and consumption of primary energy resources in the agricultural production, transporting and processing parts of the food system. The environmental impact data were obtained from results presented in Chapter 2 and 5 in this report. The food consumption profile data were derived from the results presented in Chapter 8 but in this study the food groups have been somewhat differently aggregated and, above all, the weight of different foods consumed have been recalculated to kilos primary food stuffs produced (Table 9-1). This means that losses and additions of other ingredients (such as water and sugar in bread) are compensated for. In the eco-local food basket it has been assumed that 100 percent of the food is locally produced on ERA farms and locally processed.

**Table 9-1. The Swedish average and the eco-local food baskets,** ***kg per person and year***

| | Swedish average food basket | Eco-local food basket |
|---|---|---|
| Grain products | 91 | 99 |
| Potatoes and potato products | 56 | 24 |
| Root crops | 9 | 42 |
| Fresh vegetables and fruit | 67 | 102 |
| Dairy products | 276 | 306 |
| Meat ruminants | 41[1] | 11 |
| Meat monogastrics and egg | 76 | 10 |

Four scenarios with different combinations of food consumption profiles, agricultural production systems, and food processing and transportation systems were combined to answer the research questions. The scenarios are:

1. Average Swedish food consumption, average Swedish agriculture 2002-2004, and conventional food processing and transports
2. Average Swedish food consumption, ERA farms, and conventional food processing and transports
3. Average Swedish food consumption, ERA farms, and local (small-scale) food processing and transports
4. An alternative food consumption (e.g. less and different kinds of meat), ERA farms, and local (small-scale) food processing and transports

### Pooling technique and important assumptions

To make a good comparison between conventional agriculture and ERA a pooling technique has been used. This calculates how much agricultural land from each of four different production-type farm groups (Table 5-3) is needed in order to produce the food consumed. A detailed description of the stepwise technique based on average Swedish food consumption per year and the alternative food basket in the Järna study is presented in Appendix 4.

In order to achieve a match between consumption and production when ERA farms produce the food for the average Swedish food consumption profile, some assumptions were necessary. The most important was that the consumption volumes of ruminant meat (beef and lamb) and monogastric meat (pork and poultry) had to be exchanged. In other words, the ruminant meat consumption was increased to the level of today's monogastric meat consumption but the total meat consumption was kept at the same level. The main reason for this is that ERA farming requires having a larger grassland area (at least 40 % of the acreage under tillage), and it is ruminants that can utilise the crop from this area. This means lower grain production and consequently less fodder for pigs and poultry.

## Results and discussion

Table 9-2 presents results of the pooling technique for nitrogen surplus in agriculture based on the four production-type groups of BERAS-farms compared to the average Swedish

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[1] In scenarios 2 and 3, the consumption of ruminant and monogastric meat was swapped in order to fulfil crop rotation demands and a minimum of 40 % clover/grass leys in agriculture.

agriculture. Scenarios 2 and 3 are the same because different processing and transport systems are not taken into consideration here.
Average Swedish agriculture does not fully reflect average Swedish food consumption. However when using the pooling technique on the conventional farms presented by Myrbeck (1999) we got almost the same values of nitrogen surplus (not shown) as the ones presented.

When interpreting the results, it is important to bear in mind that the land used outside Sweden for producing fodder for Swedish agriculture is not included in the average Swedish agriculture. The BERAS-farms are, on the other hand, more or less self supporting with fodder. With this in mind in the scenario based on BERAS-farms, with the same total meat consumption (but with a higher share of ruminant meat), the surplus of nitrogen (total and per capita) is only 63 % compared to the same food being produced by the average Swedish agriculture. The nitrogen surplus per hectare is also very low in BERAS production. However this scenario requires having 4.76 million hectares under agricultures production, compared to the 2.45 of today. This area is not available in Sweden. Historically the maximum agricultural area in Sweden was about 3.3 million hectares and it is difficult to imagine taking more than this into production again. However, today a large area outside Sweden is used to produce mainly fodder for Swedish agriculture. Johansson (2005) states that 3.74 million hectares are used today for producing food consumed in Sweden, implying that more than one million hectares are used abroad.

Scenario 4 assumes a more vegetarian food consumption produced on BERAS-farms. In this scenario, the area of agricultural arable land would *decrease* by slightly more than 30 % to 1.7 million hectares. And most important, the nitrogen surplus would be decreased to only 36 % of today's level and the surplus of phosphorus would be totally eliminated.

**Table 9-2. Agricultural area required and nitrogen surplus for three scenarios: Swedish average (mainly conventional) agriculture, BERAS farms producing the average Swedish food-basket, and BERAS farms producing an alternative (ecological and more vegetarian) food-basket.**

| | Scenario 1. Average Swedish agriculture 2002-04 | | Scenario 2. and 3. Swedish consumption & BERAS farms 2002-04 | | Scenario 4. Eco-local consumption & BERAS farms 2002-04 | |
|---|---|---|---|---|---|---|
| | | % | | % | | % |
| Agriculture area, million ha in Sweden | 2.45 | 100 | 4.76 | 194 | **1.70** | 69 |
| Agriculture area, ha/capita | 0.27 | 100 | 0.53 | 194 | 0.19 | 69 |
| Capita/ha | 3.67 | 100 | 1.93 | 52 | 5.29 | 144 |
| N-surplus, kg/capita | 22 | 100 | 14 | 63 | 8 | 36 |
| N-surplus, kg/ha | 80 | 100 | 26 | 32 | 42 | 52 |
| N-surplus, million kg in Sweden | 196 | 100 | 123 | 63 | 71 | **36** |

Figure 9-1 shows the results for nitrogen surplus in diagram form for the sake of comparison to the results presented in the following section.

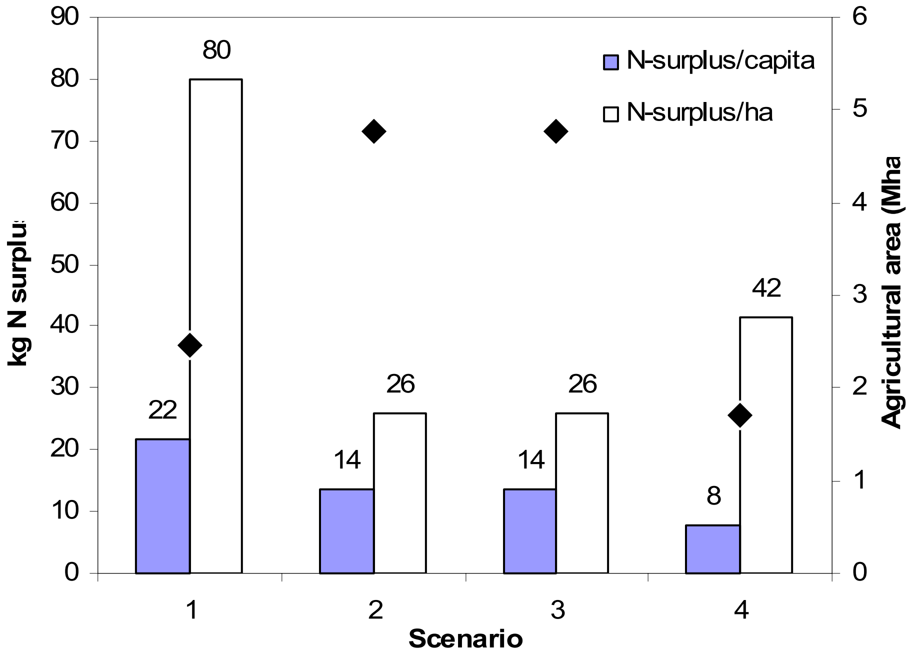

**Figure 9-1. N-surplus in four scenarios,** ***kg N per capita and kg N per ha.*** **The black diamonds represent the required area for agricultural production,** ***million hectares.***

## Global warming impact and primary energy resources consumption

Figure 9-2 and Figure 9-3 present the results for global warming impact (measured as global warming potentials, GWP, in $CO_2$-equivalents) and consumption of primary energy resources (measured in MJ primary energy resources). Here, four scenarios are included as the different systems of processing and transportation are also compared. The very low per-hectare results in scenario 2 and 3 are a result of these scenarios requiring a very large (and unrealistic) area under agriculture production.

The trends are similar to those for nitrogen surplus in both cases. However the differences between the scenarios are smaller for the GWP. For the primary energy resources consumption the relation is almost exactly the same as for nitrogen surplus. ERA production alone gives a lower global warming impact and primary energy resource consumption. When ERA is combined with a more vegetarian diet (Scenario 4), the difference is substantially lower. Processing food locally (and the resulting shorter transports) has some impact on the GWP but almost no impact on the primary energy resources consumption. The latter can partly be explained by the choice of energy carriers (fossil fuels vs. electricity) in the food processing industries and by very inefficient meat transports in the studied case. See Chapter 5 for a more extensive discussion.

Figure 9-4 present a summary of the results showing the relative difference between the environmental impacts in the four scenarios. Scenario 1 (the situation of today) is set to 1.

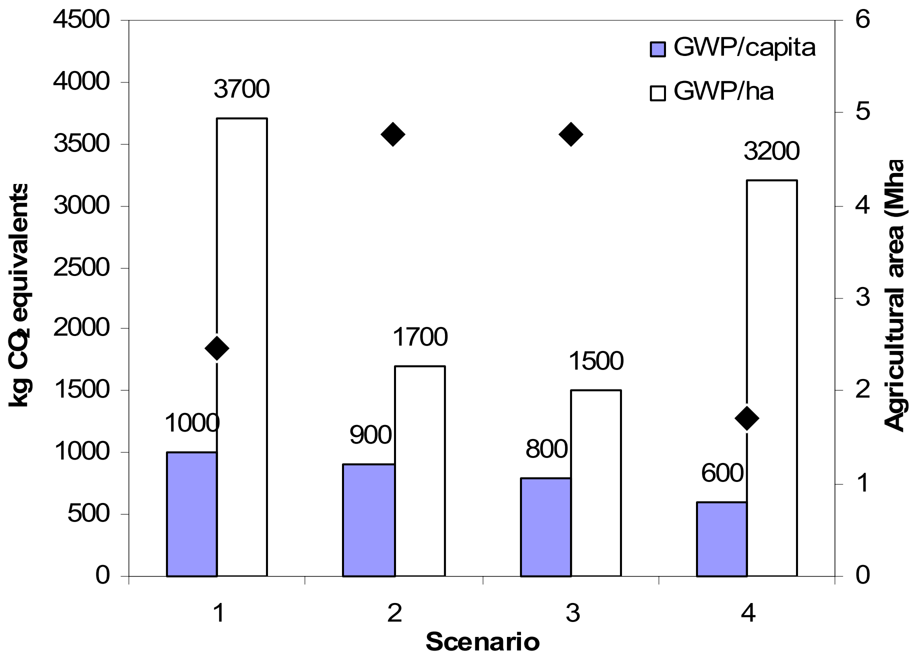

Figure 9-2. Global warming potentials in four scenarios, *kg $CO_2$ equivalents per capita and kg $CO_2$ equivalents per ha.* The black diamonds represent the required area for agricultural production, *million hectares.*

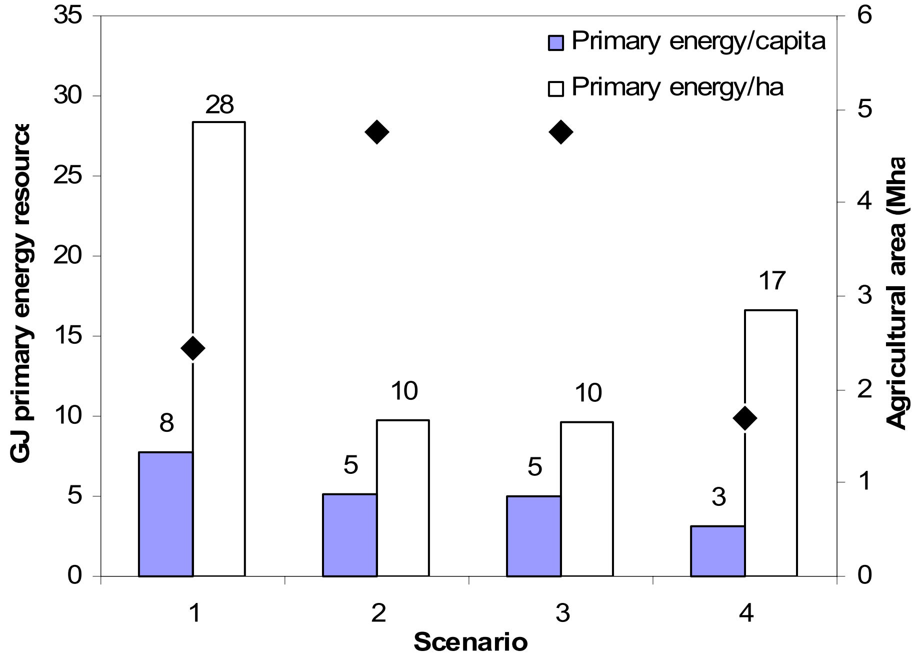

Figure 9-3. Consumption of primary energy resources in four scenarios, *GJ primary energy resources per capita and GJ primary energy resources per ha.* The black diamonds represent the required area for agricultural production, *million hectares.*

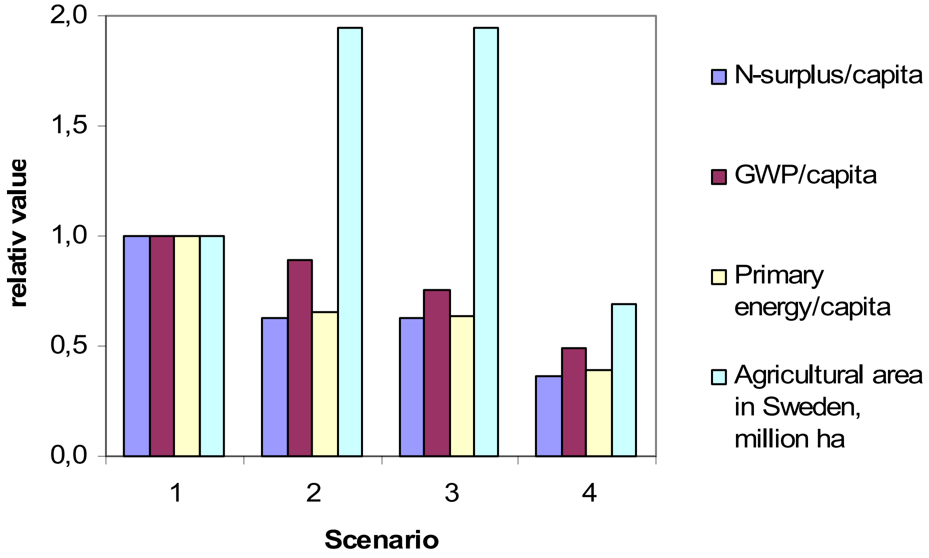

**Figure 9-4. N-surplus, Global warming potentials and Primary energy resources consumption per capita and required agricultural area in four scenarios, *relative values*.**

## *Food basket scenario, Juva Finland*

*Pentti Seuri and Miia Kuisma, Ecological production, MTT Agrifood Research Finland*

The aim of this food basket scenario study based on average Finnish food consumption was to investigate i) if it is possible to reduce nitrogen surplus of agriculture by changing agricultural production methods and ii) by how much. Existing average Finnish agricultural practises and ecological farming practises investigated in the BERAS project are compared.

### Methodology

The main production on the BERAS-farms in Juva is milk and beef. Therefore it is not possible to assemble a reliable complete food basket scenario based on the data from BERAS-farms. For this reason a food basket consisting of the Finnish average food consumption of bread cereals, milk and beef was selected for study. This represents about 50 % of the total food energy input (Ravintotase 2003). Production of the remaining foodstuffs was assumed to be unchanged and not investigated in this study.

Finnish agricultural production in 2002 was described according to the official statistics Maatilatilastollinen vuosikirja (2003) and Lötjönen et al. (2004). Agricultural land outside Finland used for producing fodder for Finnish agricultural was not included in the scenario.

Nitrogen surplus of the Finnish agriculture was estimated using two different methods. One is based on average nitrogen surplus by field area. The other is based on separating animal and crop production and looking at the field area surplus for each production line separately.

Nutrient balance data and production data for the organic BERAS-farms in Juva are presented in Chapter 2. Data from two specialized crop production farms, three milk farms and three beef farms were used for the food basket scenario. Although the crop production farms produced mainly fodder grains (oat, barley), they were used as a data source for bread grain production.

## Results

### Nitrogen surplus of Finnish agriculture

Average nitrogen surplus from Finnish agricultural practises is estimated to be 78kg/ha according to the national nitrogen balance (Antikainen et al. 2005)[1]. (See footnote a) below Table 9-3.) The Finnish agricultural statistics do not present data on field areas divided along different production lines (Maatilatilastollinen vuosikirja 2003). However, using their data, an estimation was made where half of the agricultural area was used directly for crop production on animal farms and half for crop production on crop farms.

Nitrogen surpluses were also estimated for plant and animal production areas separately using the data of Pyykkönen et al. (2004). Nitrogen surplus from field areas related to animal production has been estimated to be 116 kg/ha and from specialized crop production to be 40 kg/ha (See footnote b) Table 9-3).

### Food basket scenario

Table 9-3 presents the results for the required area and the nitrogen surplus when the food basket is produced by Finnish average agriculture, calculated with methods a) and b) and by ecological agriculture on the BERAS-farms. The required agricultural area of the BERAS farms to produce the food basket is 25 % larger than the conventional agriculture. The difference was largest for cereal production, about 50 %.

**Table 9-3**. **Agricultural area required (million ha) and nitrogen (N) surplus (kg N/ha and million kg N/food basket) for production of the average Finnish food consumption of bread cereals, milk and beef by conventional Finnish agriculture and by organic agriculture on BERAS-farms in Juva.**

| | | **Finnish agriculture 2002** | | | **BERAS farms 2002** | | |
|---|---|---|---|---|---|---|---|
| | | | | *%* | | *%* | |
| Agricultural area in Finland (million ha) | | 2.24 | | *100* | 2.39[1] | *107* | |
| Agricultural area for Food basket[2] (million ha) | | 1.06 | | *100* | 1.33 | *125* | |
| | where of bread cereals | 0.10 | | *100* | 0.15 | *152* | |
| | milk | 0.63 | | *100* | 0.84 | *132* | |
| | beef | 0.33 | | *100* | 0.34 | *103* | |
| | | **a** | **b** | | | ***a*** | ***b*** |
| N-surplus (kg/ha) | bread cereals | 78 | 40 | *100* | 36 | *46* | *90* |
| | milk | 78 | 116 | *100* | 45 | *58* | *39* |
| | beef | 78 | 116 | *100* | 54 | *69* | *47* |
| N-surplus (million kg/Food basket[2]) | bread cereals | 7.8 | 4.0 | *100* | 5.5 | *70* | *140* |
| | milk | 49 | 73 | *100* | 37 | *76* | *51* |
| | beef | 26 | 38 | *100* | 18 | *71* | *48* |
| | | 83 | 115 | *100* | 61 | *73* | *53* |

1) The agricultural area needed for BERAS agriculture was made up of the Food basket (see note 2 below) and the rest of the food consumption was kept as before.

2) The Food basket consists of bread cereal, milk and beef and represents about 50 % of the energy content of the average Finnish food consumption for one year.

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[1] It is worth noting, that nitrogen losses outside the field (mainly volatilisation) are missing from the national nitrogen balance (67 kg/ha) (Antikainen et al. 2005).

a) The division between the agricultural products was made on the grounds of average agricultural area and surplus.
b) The division between the agricultural products was made on the grounds of the surplus from the animal and crop production hectares separately.

The relative difference in nitrogen surplus in crop production and animal production of the scenarios a) and b) of the Finnish agriculture is presented in Figure 9-5. Based on the data, it is not possible to define the exact surplus from crop and animal production respectively, but method b) indicates that the nitrogen surplus from animal production is much larger than from crop production.

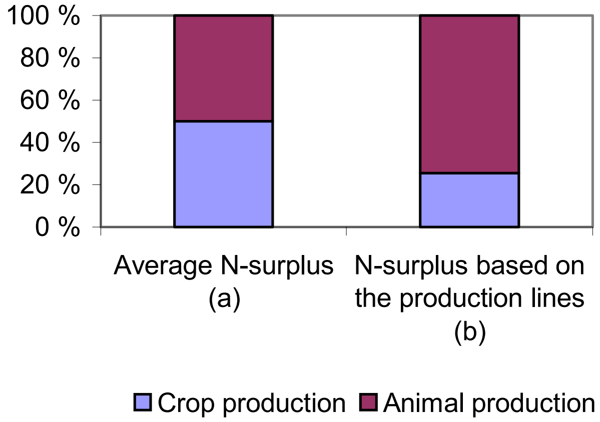

**Figure 9-5. Estimated nitrogen (N) surplus in the Finnish agriculture: average surplus (a) and surplus based on the production lines (b) (crop and animal production), relative scale % of the total agricultural N-surplus.**

The nitrogen surplus of the food basket produced by the BERAS-farms was found to be 53 % of the average Finnish agricultural surplus (Table 9-3) when the production lines were separated and 73 % when average surplus was assumed. Production of cereals on specialised BERAS-farms (based on green manuring) resulted in a higher nitrogen surplus (140 %) than production of cereals on specialised average Finnish agriculture.

Figure 9-6 shows that about 60% of the energy content of the studied food basket comes from animal products. However, the share of the nitrogen surplus from animal production is bigger than that, about 97 % on Finnish agriculture and 85 % on the BERAS-farms, calculated using method b). This means that the production and consumption of the animal products causes much more nitrogen surplus than the food crop production does, as a proportion of the energy content of consumed food.

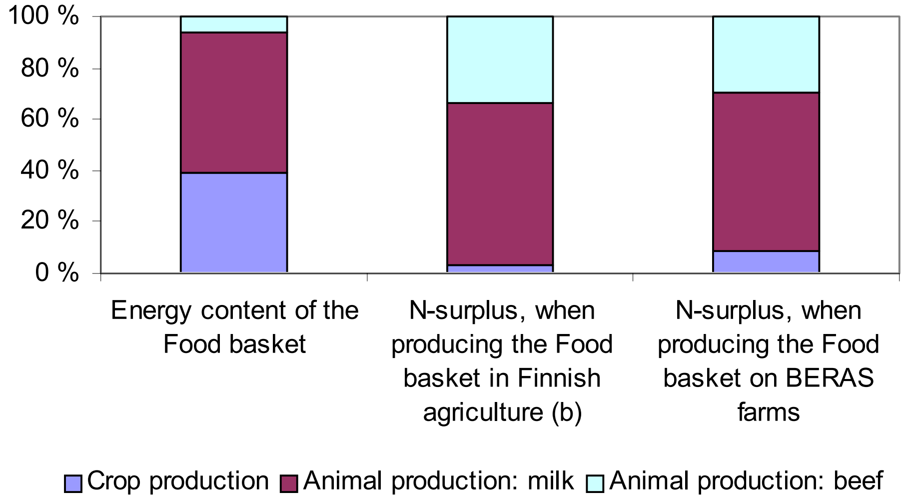

**Figure 9-6. Energy content (J) of the Food basket (50 % of the Finnish food energy consumption) and nitrogen (N) surplus (kg) of the Food basket production by two production lines: average Finnish agriculture (b= surplus based on the production lines: crop and animal production) and BERAS-farms, relative scale %.**

The agricultural land required to produce all the consumed bread cereals, milk and beef according to the methods of BERAS-farms and other 50 % of consumed food remaining as is, would be about 7 % larger than on the average Finnish agriculture (Table 9-3). If the agricultural area outside of Finland, which is used to produce fodder for Finnish agriculture had been taken into account, average Finnish agriculture would have required a larger agricultural area and more nitrogen surplus would have been generated.

The production profile of the BERAS-farms differs from the average Finnish food consumption. Main production lines, which are lacking in the studied food basket, are pork and poultry production. Nitrogen surplus from the production of monogastrics differs from that of ruminants. For this reason, the nitrogen surplus of the whole Finnish food consumption, when produced using agricultural practises of the BERAS-farms, was not possible to estimate in this study.

## Conclusions

Both scenario studies showed that the nitrogen surplus per hectare and per food basket was lower on the studied BERAS-farms.

The results in the Swedish study clearly show that changes in our food consumption can reduce the environmental impact of the food system. If these consumption changes are combined with a change in production from conventional agriculture to ERA (Ecological Recycling Agriculture) farming, a large reduction of the environmental impacts would occur. If all Swedes were to change their food consumption preferences in accordance with the eco-local food basket presented here the nitrogen surplus would decrease to 36 % of what it is today – and at the same time the area could be decreased to about 70 % of what it is today. The remaining 30 % could then be used for e.g. energy or fibre production.

Another conclusion drawn from the Swedish study is that a complete change to ERA would decrease the environmental impacts, even when the food consumption profile remains as the Swedish average of today. The agricultural area needed would, however, increase substantially making this scenario unrealistic. The conversion to 100 % ERA produced food would, thus, also require a change in people's food consumption profile.

Locally produced food showed a somewhat reduced global warming impact in the Swedish cases studied but the consumption of primary energy resources did not change.

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