

# Farming for the Future

– with a focus on the Baltic Sea Region



Artur Granstedt





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## CONTENT

- 6 Foreword
- 9 Introduction
  
- 10 The Fundamentals of Ecological Balance**
- 11 Sunlight, water, green plants – the basis of all life
- 11 Endless cycles of use and reuse
- 12 Carbon – building blocks and energy source
- 12 Nitrogen – essential to all living things
- 13 One liter of oil for each kilo of nitrogen
- 15 Just enough legumes
- 15 Phosphorus – converts energy in the cell
- 16 Balance lost
- 17 Even the ancient Romans ...
- 20 Sustainable development: a definition
- 21 Self-intensifying processes
- 22 Planetary boundaries
- 23 Fossil energy use must decrease by 80 per cent
  
- 24 The living earth**
- 25 Mineral soil
- 25 Fine distribution is the key
- 26 More acidic soils to the north
- 27 Humus, a millennium in the making
- 27 Where organic processes meet dead mineral
- 29 Fertile soil is self-regulating
- 29 Tilled soil, an ecosystem
  
- 30 In a Global Perspective**
- **Arable land and the planet’s food needs**
- 33 Migration
- 33 900 times more
- 34 Life-giving alluvial silt
  
- 35 A history of farming in the Baltic Sea Region**
- **From slash-and-burn farming to broken biocycles**
- 36 “Farmland is a child of the meadow”
- 36 Legumes in the meadow and fallen leaves fertilized the soil
- 39 Legumes put an end to famine
- 40 Clover feeds animals and soil alike
- 41 The dispersion of farmsteads – an agrarian revolution
- 43 How knowledge spread
- 44 Closed cycles on every farm
- 46 Broken biocycles
- 47 Increasing waste
- 51 Since 1950, two farms out of three no longer exist
  
- 53 Bright Green, Weed-Free Fields**
- **the consequences of specialization**
- 54 How the problem of nutrient losses arises
- 56 Nitrogen
- 57 Phosphorus
- 58 About 40 000 square kilometers of dead seabed
- 59 The environmental load, per hectare and overall
- 61 An objective never attained
- 65 The spread of toxins in the environment
- 66 ‘Low-dose’?
- 68 Cadmium pollution is still with us

- 68 Cruelty to animals
- 70 Grazing animals are better off – but their lives, too, are short
- 71 From energy producer to energy consumer

#### **74 The Alternatives – biodynamic, organic and ecological agriculture**

- 75 A Nordic green platform
- 76 The breakthrough
- 77 The rules

#### **79 Goals within reach – the BERAS project**

- 81 Not a question of turning back the clock
- 84 Fertility can be restored
- 86 Legumes do double duty

#### **87 The food we eat and its impacts on the environment and climate change**

- 87 Food from ERA farms
- 89 The impact on the sea
- 90 Impact on the climate
- 93 Impact on biodiversity

#### **94 Taking the step**

- 94 Wherever the land is arable
- 94 Economic possibilities
- 95 Stumbling blocks
- 96 Yields and profitability
- 98 Chemical agriculture is demanding
- 100 Ecological Recycling brings better nutrition

#### **101 The outcomes at BERAS farms**

- 102 Sweden
- 102 Nibble Farm
  
- 107 Finland
- 107 Pargas Farm
- 109 Rekola Farm in Häme
  
- 113 Latvia
- 113 Zageri
- 115 Straumali and the ecological Pagasta Dairy

#### **117 Conserving resources – measures and benefits**

- 117 The ecological foundation
- 117 Mälby farm
- 122 Better returns to the farmer – and to the country

#### **Summary**

- 124 The BERAS Project – Published reports and summary

## FOREWORD

The modernization of Swedish and European agriculture in the past century has increased yields immensely. At the same time, modernization has led to a uniform, biologically depleted agricultural landscape and a number of other negative impacts. Most serious of these impacts are reduced biodiversity, pollution of water and the air, the spread of toxins in the environment, climate-changing emissions, and the loss of cultural capital.

Most of the environmental impacts of farming relate to land use and the intensity of that use. Generally speaking, the greater the intensity, the greater the impacts. Agriculture of yesteryear, with its close coupling of crops and animal production, reliance on local resources, small scale and variety was environment-friendly and depleted very little of our planet's basic natural resources. It was conducted in – and it created – an agricultural landscape that produced important natural and cultural assets. Among these assets were pastures and meadowland with their wealth of species.

There is no returning to the agriculture of the past, but older practices have left us a heritage that we can learn from and make use of. In the interests of nature conservation efforts are being made to preserve the remnants of old-time agricultural landscapes, particularly through the extension of environmental compensation to their custodians. Beyond that, there are aspects of the older farming practices that may be adapted and applied to improve farming practices today and in the future. Not least, they can help to reduce the environmental impacts of the larger scale and increasing specialization of farms to produce either crops or animals. Specialization has increased the need for synthetic fertilizers in the one case and imported fodder in the other. The lessons of older practices can reduce that need.

The imbalance between fodder production and the scale of animal production on larger animal farms has serious and far-reaching consequences. It leads to surpluses of manure and urine, which then leak plant nutrients to surrounding streams and bodies of water. The load of nitrogen and phosphorus originating in agriculture is the prime cause of eutrophication of the Baltic Sea and poses a serious threat to this sensitive, virtually land-locked sea. A lot has been done – and is being done – to reduce the pollution of the sea, but the measures taken all fall within the framework of current agricultural practices. The same is true of other sectors, as well. They are necessary, but not sufficient.

The more we learn about the sea, the clearer it becomes that agriculture – and other sources of pollution – must do far more than is being done today. Otherwise, we risk cementing an untenable environmental situation and will lose, once and for all, the vital ecosystem services that the Baltic can produce. To reduce the load of nutrients emitted to the sea requires much more than continued trimming of conventional practices and fine-tuning of our environmental mindfulness. We have to explore ways to reform the entire model that leads farming to pollute in the first place.

Conversion to Ecological Recycling Agriculture (ERA), the subject of this book, may be one way to achieve such a comprehensive system reform. BERAS (Baltic Ecological Recycling Agriculture and Society), an EU-supported project conceived and directed by Artur Granstedt between 2003 and 2006, involved farms in all the EU Member States around the Baltic Sea. It represents a broad, holistic approach to the ways in which conversion to ERA methods can both reduce effluents from farming to the sea and lighten the environmental impacts of farming more generally.

The results of the project are encouraging. Consequently, it is currently being followed up in a new EU project, BERAS Implementation, which will continue through 2013 under the same leadership, but with many more participating partners (27 all told) in the countries around the Baltic.

In focus now is the actual transition from conventional practices to ERA with a view to identifying policy measures that can facilitate the transition. The study covers numerous aspects of both agricultural methods, with model farms and continued field trials, and empirical study of food preferences and patterns of consumption.

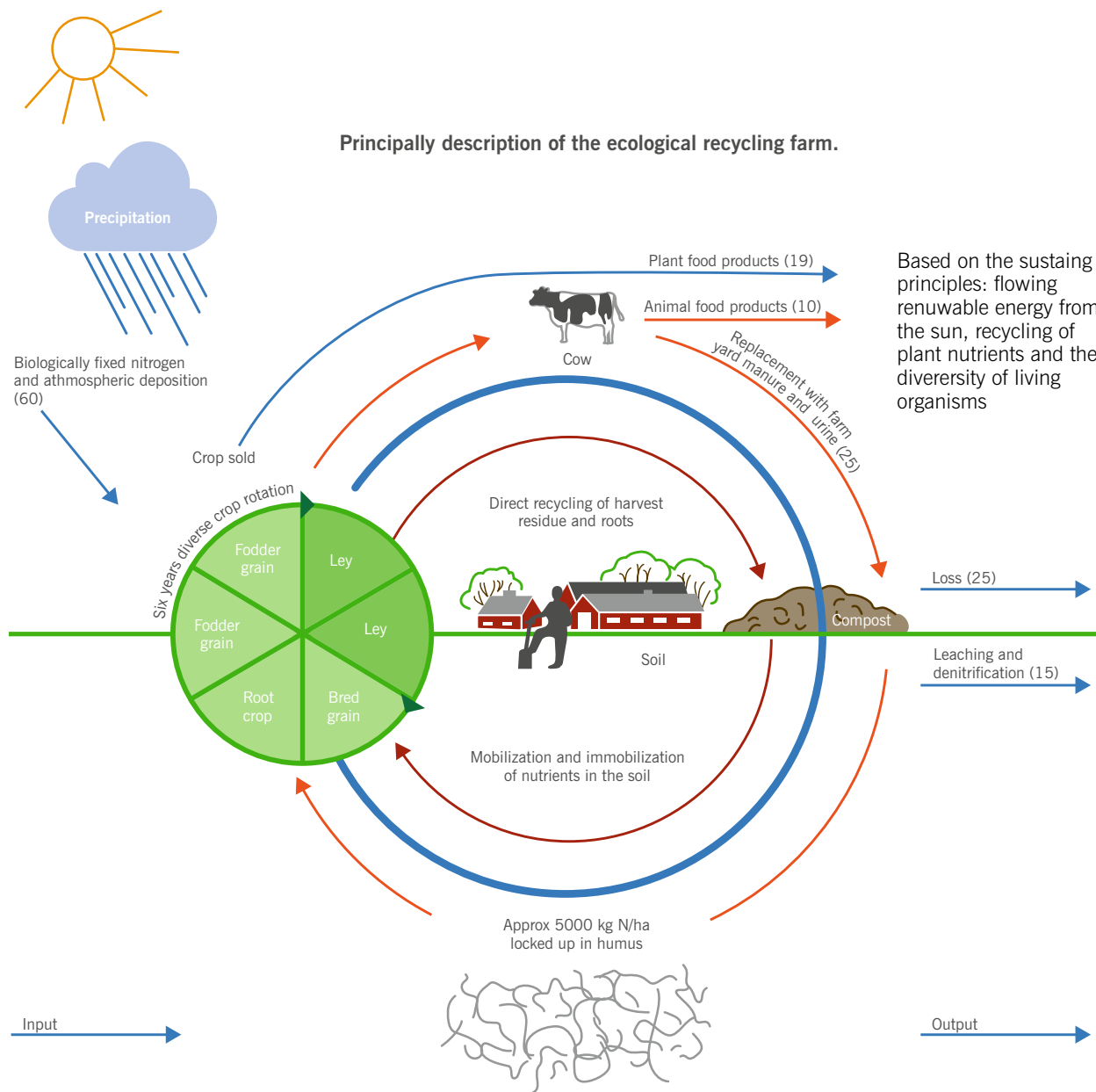
Farming for the Future is the fruit of decades of experience of research on organic agriculture on the part of the author. It explains the biological, chemical and physical principles of ecological recycling agriculture, the practices that lead to good harvests and good economic returns, and the consequences of ERA for the farmer, the environment, consumers and society at large. It offers a holistic view of the environmental problems associated with conventional farming practices and the role of agriculture in a broader societal perspective, with a particular focus on how patterns of resource use and the scale and structure of the sector relate to environmental pollution.

The book is an important part of the work being done in BERAS Implementation to spread awareness and knowledge about ERA methods and to encourage conversion to ecologically sustainable methods. This applies both in Sweden and other countries around our common sea. For that reason the book is being made available in both Swedish and English.

*Per Wramner*

Professor of Environmental Sciences,  
COMREC, Coastal Management Research Centre  
Södertörn University





Based on the sustaining principles: flowing renewable energy from the sun, recycling of plant nutrients and the diversity of living organisms

*Schematic illustration of the Ecological Recycling (ERA) farm, based on energy flows from the sun, from recycled resources, and biodiversity. Three biocycles described here: 1. The internal cycle, i.e., the annual flows of nutrients and organic matter between the soil and crops, the roots and waste of which are continuously returned to the soil, where they contribute to the formation of new organic matter and the mineralization (freeing) of nutrients for coming years' production. 2. Crop rotation (in this case a 6-year cycle): The succession of crops is purposeful. Ley, consisting of grass and legumes like clover and lucerne, are nourishing; the biomass they build up and the atmospheric nitrogen they accumulate generate and enrich humus in the soil. Cereals, fodder grain and root crops are, on the other hand, extractive; more humus is depleted than is built up. 3. The greater cycle: A greater share of the harvest from the farm feeds its animals, here symbolized by a cow. The animals' urine and manure, rich in nutrients and humus-building matter, are returned to the soil via compost and careful application of manure to the soil, from which the nutrients came. The cycle consists of four elements, among which the soil and its living organisms (as much as a ton of earthworms per ha) are the prime resource base. In the center of all this is the farmer, who, by doing the right thing, can improve the productive capacity of the land, the quality of the crops it produces, and the well-being of the farm's animals and humans alike. We all play a part. Source: Granstedt, A (1992) The potential for Swedish farms to eliminate the use of artificial fertilizers. American Journal of Alternative Agriculture 6:3:122-131.*

## INTRODUCTION

Every minute of our lives, every breath we take is made possible by the food we eat. Bread, vegetables, meat and dairy products, all come originally from crops that grow in the soil. Today we are seven billion people who share the planet – in thirty years' time (soon enough that most of us who are alive today will experience it) planet Earth will have perhaps 2-3 billion more mouths to feed. We face the double challenge of at once feeding a rapidly growing population with sufficient amounts of wholesome, nourishing food, and economizing with finite resources in order to stop the depletion of the basis of all other resources: fertile soil and the plant life it sustains. It is the flow of energy from the sun that, via the vital processes of green plants, regenerates the planet's ecosystem and creates the renewable resources on which our existence depends. Agriculture and forestry imply production, but also custodianship of the basis of our existence: arable, fertile soil. The ways we go about farming and forestry are crucial to the ecological future of the planet. Thus, they are literally 'matters of life and death' to each and every one of us.

This book discusses the ecological premises for sustainable agriculture and, thereby, sustainable existence. Using examples from throughout history, it describes how humankind has broken the fundamental rules of Nature that make our existence viable in the longer term, which in turn has led to current crises like eutrophication and wasteful consumption of natural resources. But, it also describes how we can stop breaking the rules and change over to highly productive farming and forestry practices based on local and renewable resources that do not deplete, but instead enhance the fertility of the soil. We have the necessary knowledge and can do this, if we have the will; that is, if we do not let ourselves be blinded by shortsighted solutions. The choices involved are approached from the point of view of biology, economics and politics, with practical examples of sustainable farming and sustainable food consumption.

The factual basis of the book derives from years of research and studies of how organic farms can be organized so as to be truly sustainable and environment-friendly. Between 2003 and 2006, these studies involved collaboration with about fifty research colleagues in the countries around the Baltic Sea in the BERAS (Baltic Ecological Recycling Agriculture and Society) project. Since late 2008, the project continues in the form of "BERAS Implementation", which will continue until 2013. Forty-eight organic farms that fulfill the criteria that ensure true sustainability and environmental soundness in the eight EU countries surrounding the Baltic Sea have been documented. The farms demonstrate how farming in the respective countries might be done in the future. Other links in the food supply chain have been studied, as well. The studies show how local processing, short transport distances, modified diets and farm-based biogas production can result in substantially milder climate impacts. The BERAS project, financed by grants from the European Union, has been documented in national and international research reports.

Farmers, students of agriculture and others who wish to know more about the subject will find footnotes throughout the book that refer the reader to relevant sources in the literature and research material. Boxes offer background and more detailed information.

## THE FUNDAMENTS OF ECOLOGICAL BALANCE

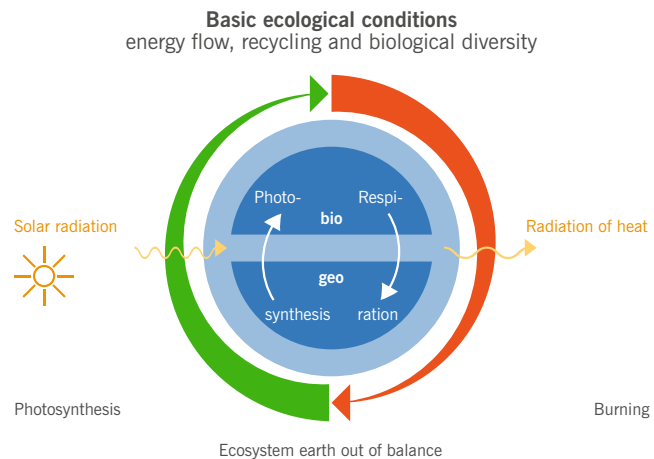
How the perfectly balanced conditions that make life possible, that allow plants to bind solar energy and convert it into nutrients for other living organisms in an eternal recycling of carbon, oxygen, hydrogen and nitrogen, came to be is a mystery. But, over the past 150 years, human activity has disturbed the balance to the extent that global ecosystems are being altered.

The living Earth, the biosphere, covers our planet like a thin membrane. It is in this membrane or 'skin' that the delicate balance of chemical, physical and climatic conditions that make life possible operates. The remarkable thing about life (as opposed to the mineral realm) is that living beings are self-organizing and co-create the conditions for one another's existence. Life creates order and ever-more complex structures. Starting with simple unicellular organisms, a differentiation takes place toward the complexes of organs and functions that sustain higher orders of animal life, including us human beings. When life ends and a living organism dies, its body decomposes into mineral elements that characterize the inorganic realm. Life can only be created by life, and the inherent characteristics of each species are unique and irreplaceable. The branch of knowledge that relates to living organisms and how they interact with each other and their surroundings is called Ecology.

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Figure 1. The relationship between living and non-living elements in the ecosystem of the soil. Sunlight reaches the Earth as high quality short-wave energy and fuels biological processes. By means of the process of photosynthesis materia is transferred from the simple inorganic matter in the non-living (abiotic) 'geo' realm to the complex, energy-rich organic matter of the 'bio' realm. The process results in low-quality longwave heat being emitted out into space. Entropy is reduced, and order increases in the former process (photosynthesis), whereas the decomposition of organic matter (exhalation) leads to an increase in entropy, disorder, and waste matter is freed. Today, the latter process predominates due to our exploitation of fossil energy (i.e., stored sunlight), deforestation and soil degradation. (After Hubendick, 1985) <sup>1</sup>

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<sup>1</sup> Hubendick, 1985. Människoekologi. Gidlunds förlag. Stockholm

### Sunlight, water and green plants – the basis of life

About one per cent of the solar energy that reaches the vegetation on planet Earth is bound through photosynthesis. Sunlight is assimilated by the chlorophyll in plants' leaves. The energy is bound in the form of energy-rich organic matter that provides nourishment to other living organisms, with life-giving oxygen as a by-product. Plants are the basis for all food chains. They modulate flows of water and protect fertile topsoil, while the withered remains of dead plants are gradually converted into fertile soil that provided nutrients for new plant growth.

A fundamental prerequisite for photosynthesis is water. The energy plants generate cleaves water,  $H_2O$ , into its constituents, hydrogen and oxygen. The hydrogen then reacts with carbon dioxide to form carbohydrates, whereas the oxygen is released into the air.

When respiration and combustion takes place, matter is broken down into its constituent elements; oxygen is again united with the hydrogen in carbohydrates to form water. Carbon dioxide is released to the atmosphere and energy is generated, but now in the form of low quality heat that emanates out into space. Photosynthesis and respiration are the two essential processes that make life possible (Figure 1).

### Endless cycles of use and reuse

Characteristic of all living organisms are the cyclical processes whereby individual substances are used and reused, again and again. The processes are fueled by solar energy. The basic elements, carbon, oxygen, hydrogen and nitrogen, are assimilated from air and water to become the principal ingredients in the substance and metabolic processes of

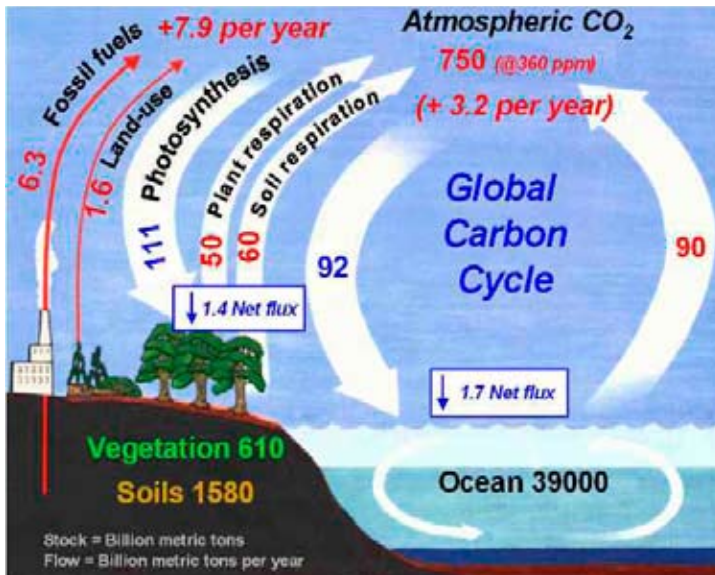


Figure 2. The global circulation of carbon between soil, air and sea. In a balanced system, the amount of carbon that is bound through photosynthesis is equal to the amount released through combustion. That balance is out of kilter today. Our exploitation of fossil carbon stores (oil, coal and gas) and the net depletion of carbon stores both in the soil (destruction of the humus layer) and in global biomass (deforestation) means that today, an estimated six billion tons more carbon is released to the atmosphere (in the form of carbon dioxide) than is bound through photosynthesis. Each of us participates directly in this biocycle. We, like all other animals, exist thanks to the plants we consume and the air we breathe. Source with permission: Dr. George W. Kling, University of Michigan, USA.



The chemistry of carbon is also the chemistry of life

living cells (Figure 1). The soil is the source of minerals like phosphorus, potassium, calcium, sulphur, magnesium and several essential tracer elements that take part in vital processes and make up organic substance. Two key elements in all living matter are carbon, which is the least component in air (0.04%) in the form of carbon dioxide, and nitrogen, the most plentiful component (78%).

#### **Carbon – building blocks and energy source**

Plants assimilate carbon out of the air, and oxygen is released to the air. Carbon forms part of the carbohydrates that provide energy to living organisms, while it is also a vital constituent in the structure of all organic matter. The chemistry of carbon is also the chemistry of life. In exhalation carbon is returned to the atmosphere in the form of carbon dioxide. The air currently contains 0.039 per cent CO<sub>2</sub> by volume, which amounts to 780 billion tons of carbon in the atmosphere around the planet as a whole. Nearly 15 per cent of the Earth's atmospheric stores of carbon are assimilated by vegetation each year. The process results in an increase in the concentration of carbon, from about 0.04 per cent in the air to nearly 50 per cent in organic dry matter. Inhalation and exhalation also mean that a quantity corresponding to all the atmospheric carbon surrounding planet Earth is circulated through terrestrial organisms in just seven years' time (Figure 2).

We do not really know how the exact balance of conditions that allow life to exist on our planet – temperature, air, water and nutrients – has developed or how it is maintained. But we do know that human activity has tampered with the balance these past 150 years so that it now has global consequences for our planet's ecosystems. The increase in the level of carbon dioxide in the atmosphere is one example. Despite its low concentration in the atmosphere any increase has palpable effects on the climate. The balance between combustion and photosynthesis has to be restored, which means that we must adapt our energy use accordingly if we are to avoid a global rise in temperature.

#### **Nitrogen – essential to all living things**

Nitrogen's biocycles are the keys to life. They are just as crucial as photosynthesis and breathing. Nitrogen is the dominant ingredient in the atmosphere: 78 per cent of the air we breathe is nitrogen gas, constituted by a strong molecular bond, N<sub>2</sub>, i.e., two mutually binding nitrogen atoms. Under natural conditions these nitrogen atoms do not react with other elements, in contrast to the so-called reactive nitrogen found in various chemical compounds. When oxygen is heated up under high pressure together with hydrogen, the result is ammonia, NH<sub>3</sub> (the Haber

process). When oxidized, ammonia produces nitric acid. Both ammonia and nitric acid are highly reactive and are used extensively in chemical industries and in the production of synthetic fertilizers. Saltpeter was once manufactured using the nitrogenous salts that form in barnyard manure. Reactive nitrogen in saltpeter is also a principal ingredient in the gunpowder used in the ammunition Western countries used to build their empires, and explosives used in the mining industry.

Like carbon, nitrogen is a principal ingredient in all living things. Whereas carbon supports the structures in living things, nitrogen is in the proteins that support the processes by which living cells survive, synthesize new proteins and reproduce. Nitrogen is a fundamental ingredient in all amino acids and proteins and the nucleotides that bear organisms' gene plasma and energy supply systems. It is also an ingredient in chlorophyll, the agent of photosynthesis in plants. The enzyme systems in living organisms consist of proteins that also form their own basic substances. Amino acids, without which there would be no life, are created out of inorganic ammonia and nitrate ions that are absorbed from the moisture in the soil. These self-organizing processes mean that life can only be produced by life. Photosynthesis, the process by which solar energy is trapped with the help of nitrogen-based chlorophyll, and the solar-powered biological fixation of atmospheric nitrogen are examples of how living processes also are interdependent, both within individual organisms and in the interaction between organisms.

Some of the proteins that we and animals absorb from what we eat are broken down so that the amino acids that were originally created by vegetation can be used to form bodily protein. Much of the protein content of food is broken down more completely so that we can use the energy and other nutrients in them. In the process, the nitrogen that is bound up in protein is given off in the form of mineral nitrogen compounds in our bodily excretions (faeces and urine).

Alongside carbon, nitrogen is a principal constituent in humus. Under natural conditions, nitrogen is scarce – despite the virtually infinite amount of nitrogen in the surrounding atmosphere. This scarcity is due to the fact that it requires a great amount of energy to convert the nitrogen molecules in the atmosphere into reactive ammonia and nitrates that can become part of various chemical compounds that can be drawn into vital processes.

### **One liter of oil for each kilo of nitrogen**

The industrial process by which we human beings can fix nitrogen from the air requires the energy in one liter of petroleum (40 MJ) for each kilo of nitrogen produced. This amount of fossil energy has a greenhouse effect



Nitrogen is a fundamental ingredient in all amino acids and proteins and the nucleotides that bear organisms' gene plasma and energy supply systems



Biologically accessible ammonia is created at cellular and molecular levels, with no need of a factory or fossil energy, and without producing climate-altering emissions

equivalent to 3 kg of CO<sub>2</sub>. In addition, the process itself gives off nitrous oxide (N<sub>2</sub>O, a.k.a. laughing gas), a potent climate-altering gas, having a climate effect equivalent to 3 more kg of CO<sub>2</sub>. New technology is being developed that may reduce the emissions of the process considerably.

In Nature, the energy-demanding task of fixing atmospheric nitrogen is powered by renewable solar energy. Here, the nitrogen is trapped biologically using the photosynthetic process as the energy source. Biologically accessible ammonia is created at cellular and molecular levels, with no need of a factory or fossil energy, and without producing climate-altering emissions.

We now know that biological nitrogen fixation takes place in living cells with the help of nitrogenase, an enzyme that has the ability to split molecules of atmospheric nitrogen to permit the formation of minerally reactive ammonium nitrogen, which is the precondition for synthesis of amino acids and the development of protein in plants. There are free nitrogen-fixing organisms in the soil that thrive on the products of decay, and there are organisms that live in direct symbiosis with a good number of species of legumes, among other plants. Through photosynthesis the host plant binds solar energy, which in the form of sugar compounds is transported down to tubers, thus fueling the process. The greatest input of nitrogen into the planet's ecosystems takes place through metabolic fixation of gaseous nitrogen oxides by marine cyanobacteria and plankton. A lesser amount of nitrogen is supplied from the atmosphere in conjunction with lightning, which produces nitric oxides that plants can metabolize.

It is important to distinguish between the principal forms of nitrogen in the environment:

1. Non-reactive atmospheric nitrogen (N<sub>2</sub>)
2. Reactive mineral nitrogen, ions of which may be dissolved in soil moisture (NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>) or in the air as ammonia (NH<sub>4</sub>) or nitrous gases (NO<sub>x</sub>)
3. Organically bound nitrogen in biomass (in humus and all living organisms).

Nitrogen in forms that are accessible to plants is essential to all life processes in the realm of plants. It provides nutrition for all living organisms, and nature has found a way to ensure the supply. Too little nitrogen stunts growth; plants' leaves turn yellow, and photosynthesis comes to a halt. Too much nitrogen in the soil results in a surfeit of nitrogen in the plant, leading to too rapid growth. An overabundance of nitrogen leads to an imbalance, which may lead to shortages of other nutrients in the plant. Its tissue may be weakened, leaving it more vulnerable to injury and disease.



### Just enough legumes

Legumes (Leguminosae: peas, clover, etc.), which fix nitrogen symbiotically in their root systems, are present in natural vegetation to an extent that matches the nitrogen needs of other plants. When legumes die and decompose in the soil, the nitrogen in them becomes available to other plants. Over the eons vast amounts of nitrogen have been accumulated and are stored in soil organic biomass, mostly as humus. One hectare of a mineral soil having, for example, a humus content of three per cent contains five tons of nitrogen and 50 tons of carbon in the topsoil to a depth of 20 cm.

In natural ecosystems most plants are not nitrogen-fixers. They get the nitrogen they need from dead and decaying organic material and the decomposition of humus itself, so-called mineralization. Most of the nitrogen circulates in a closed circuit between living, dying and dead organic material with low losses to the environment. The mineralization process requires a constant supply of new organic plant material and the presence of symbiotic nitrogen-fixers. In marine environments under natural conditions this need is filled by nitrogen-fixing cyanobacteria in addition to the organic material that is carried to the sea from terrestrial ecosystems.

The flows of nitrogen throughout ecosystems may be described in terms of two cycles: an internal biocycle and an external bio-geochemical one. The internal biocycle takes place in the interaction between soil and plant life, in which nitrogen from decaying plant material, excrement and humus can be recycled again and again. The external bio-geochemical cycle takes place between the biosphere and the atmosphere when nitrogen is fixed through biological processes and is then returned to the atmosphere in the form of nitrogenous gases. In modern industrial society there is also a fallout of nitrogen compounds from the air (exhaust from internal combustion engines and industrial fuel use) that vegetation can make use of and an artificial contribution of industrially fixed atmospheric nitrogen in the form of synthetic fertilizers (nitrogenous salts) on agricultural land.

### Phosphorus – transforms energy in the cell

Phosphorus is vital to all organisms. It is essential for the synthesis of carbohydrates, the cells' energy supply, and the genetic information systems of all living things. Like nitrogen, phosphorus circulates in closed organic biocycles between plants, other living organisms and the soil. When organic matter is mineralized in the soil, organically bound phosphorus is released. Sulphur, a good share of which is bound in organisms, is released, too, and returns to the soil via plant waste and other organic waste from the vegetable and animal kingdoms. Other minerals that

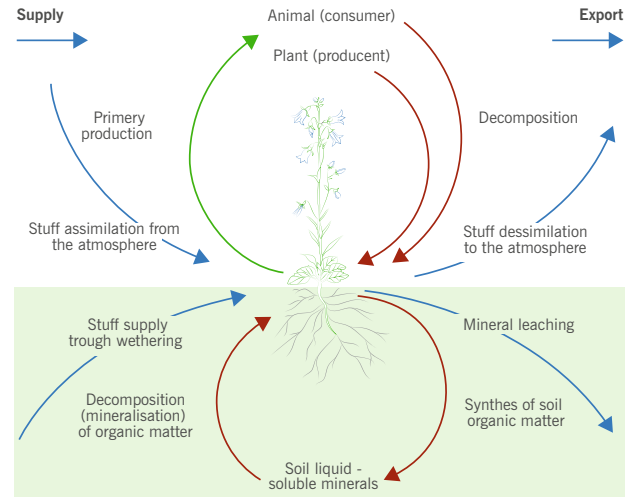


Figure 3. External and internal cycles with the plant as the link between the cosmos, the atmosphere and the soil. Only when we sow a living seed in the soil is it possible for dead inorganic matter to become part of a new life. Carbon and nitrogen from the air, and other minerals from the soil are combined to form living matter of increasing complexity and greater order. Only life can produce life. The process is fueled by sunlight, whose energy is assimilated by the vital processes performed by chlorophyll in green leaves. In the Fall, when vegetation withers and dies, living agents of decay come in to do their work. Some of the organic matter is converted to humus in the soil. The mineralization of plant waste and humus in the soil, a process whereby the material once again is converted to inorganic matter, produces nutrients for the coming spring and summer, when vegetation once again makes use of sunlight to produce nutritious plants. All other living organisms live off these abilities of plants, and their remains, too, are ultimately mineralized and produce nutrients in the soil.

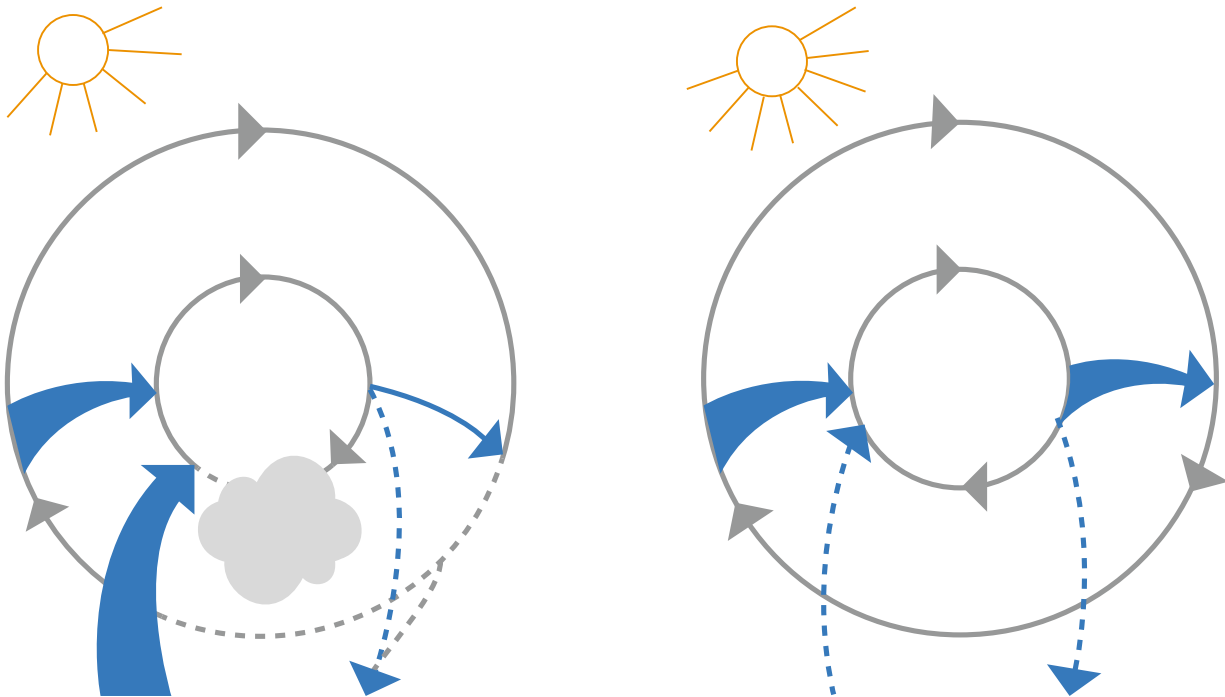


Figures 4a and 4b. Natural bio-geochemical cycles involve all the substances that are to be found in vital ecosystems, e.g., carbon, oxygen, nitrogen and all the minerals that living organisms are made of. Cycles in the technosphere include all the substances that human beings extract from Nature and use for technical utility articles and tools, machines, transport vehicles and even housing and other structures. In addition, there are all the chemical compounds and products that we manufacture and use. Figure 4a shows how metals and minerals that are not recycled accumulate in the environment and are dispersed as molecular trash and will remain dispersed in the foreseeable future. Figure 4b shows how all things might be reused so that all the problems are eliminated. We are all learning to sort our waste and recycle it, but we have a long way to go before we achieve a true 'Recycling Society'. Vast amounts of extremely hazardous substances have been irretrievably dispersed. Hazardous substances that cannot be contained in safe, closed systems should not be allowed to exist.

recycle in this manner are calcium, magnesium and the whole spectrum of tracer elements. Unlike nitrogen, which originates in the air, phosphorus and other minerals are brought into the biocycles from weathering rock. Soil contains between 0.02 and 0.2 per cent phosphorus. Phosphorus is naturally present in all mineral soils, where it slowly weathers and turns into phosphate salts that are accessible to plants. The slow rate of transformation limits the availability of phosphorus to an amount corresponding to what natural ecosystems require. Shortages arise mainly when cyclical flows are broken, and access to too much readily soluble phosphate can result in uninhibited biological growth. Topsoil that consists of 3 per cent organic matter contains 5 metric tons of nitrogen per hectare, but furthermore, roughly one ton of phosphorus. About 1 per cent of this phosphorus is mineralized during the growing season and becomes available to plants – in addition to what is released from other organic material that is added to the soil.

### Balance lost

There are two kinds of 'cycles'. On the one hand we have the biogeo-cycles we find in Nature; the others are man-made, technological cycles (Figures 4a and 4b). Figure 4a illustrates how man-made cycles are only partly cyclical. Modern industrial society has drastically altered the carbon and nitrogen cycles, the phosphorus cycle, and even the sulphur cycle. The extraction of mineral ores from the Earth's crust produces



hazardous waste that has serious impacts on soil, water and air. In addition, there are the many relatively recent, man-made chemical substances that natural processes are not equipped to deal with. Nor is Nature prepared for genetically modified organisms. Figure 4b describes biocycles where there is a balance between building up and breaking down, in both natural cycles and a technosphere that provides for repeated use of minerals and other substances.

### Even the ancient Romans ...

In the past 10 000 years humankind has learned to influence natural ecosystems, the land and its flora and fauna to enable us to grow more food. This has changed the landscape. The cultivated landscape has its own ecosystems, agro-ecosystems. They are driven by solar energy and maintained by human labor and deliberate regulation of crops, animal species and growing conditions. The history of cultivation offers examples of both successes and failures that have had consequences for people's nutrition and the rise and fall of civilizations. The once so enormously wealthy and powerful Roman empire around the Mediterranean is a recent example of what can happen when a society depletes its resource base. Unsustainable farming practices, excessive grazing and deforestation used up the natural resources on which the empire depended. As a consequence, people migrated and took over new territory. If we go even further back in time or further afield, we find similar examples. There is, for example, considerable evidence that ancient Mesopotamia, often called 'the cradle of civilization', declined because the soil lost its fertility and sophisticated irrigation systems collapsed, leaving the once bountiful land between the Tigris and Euphrates rivers a salty marshland.<sup>2</sup>

Today, nearly all of the planet's arable soil is in use. Land that has been lost through erosion and humus loss is now being compensated for with land that has been made available through the destruction of forest, despite the fact that forests, too, are an endangered resource. In many parts of the world erosion is occurring at a rapid pace. Soil loss in Ethiopia is a prime example, which was discussed at the UN Climate Conference in Copenhagen. A century ago more than half of Ethiopia's territory was forested; today the figure is only about three per cent, and more than one billion tons of soil are estimated washed away each year from the once fertile highlands. Destruction of the soil is a major problem in developing countries and in many other places, as well.

The dynamic balance between constructive and destructive processes in Nature has developed over the millennia. In global terms, human use of the soil has been relatively minor in its extent. It is only in the last

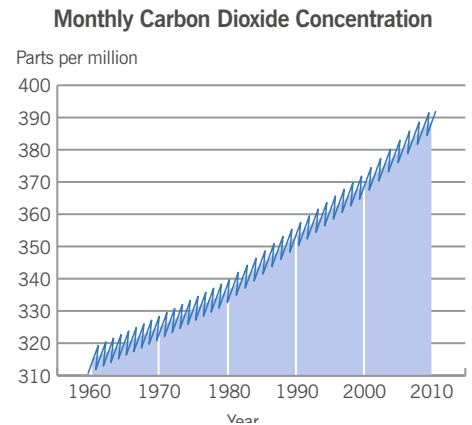
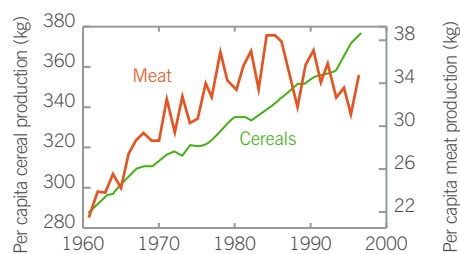
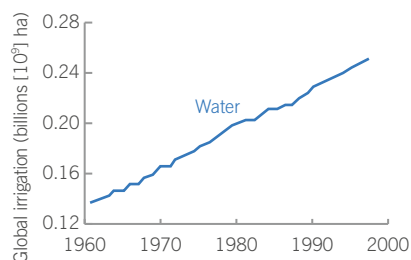


Figure 5. The so-called 'Keeling curve', named after its creator, shows the increasing concentration (ppm) of CO<sub>2</sub> in the atmosphere. The zig-zag line indicates variations due to seasonal variations in vegetation, with plants in the northern hemisphere more predominant in the Spring and Summer months. When plants die and decay (or shed their leaves, which decay) in Fall and Winter, the carbon dioxide concentration rises once again. As the curve indicates, more carbon dioxide is emitted to the atmosphere than vegetation can bind. Human activity is the cause, and we are experiencing more and more the ecological and economic consequences of this man-made imbalance. Recent Mauna Loa CO<sub>2</sub> in atmosphere March 2012: 394, 45 ppm. Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Research, March 2012. <http://www.esrl.noaa.gov/gmd/ccgg/trends>.

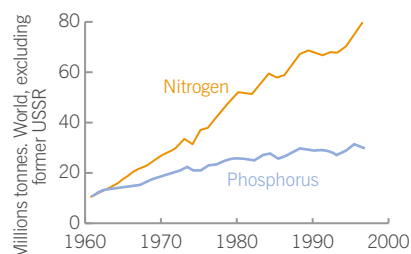
**Global trends in cereal and meat production**



**Increased use of irrigation**



**Global total use of nitrogen and phosphorus fertilizers**



**Total global pesticides production**

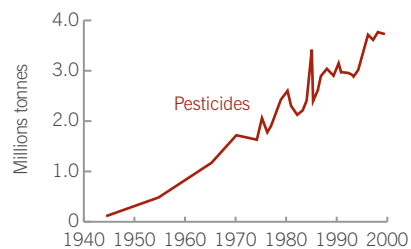


Figure 6. Global trends in food production, use of nitrogen and phosphorus fertilizers, use of irrigation, and total production of pesticides. Source: Tilman, D et al. (2002) <sup>5</sup>

century – and the last fifty years in particular – that the balance between constructive and destructive processes has been disturbed by human activity to such an extent that it has global consequences. The conversion of pristine lands to agricultural land has meant that 60–75 per cent of the planet’s stores of bound carbon in the form of humus has been freed.<sup>3</sup> The process of breaking down and freeing the world’s stores of bound carbon can be stopped. Agricultural systems that include several years of grass land cover have a considerable potential to reduce the emission of greenhouse gases to the atmosphere and actually reverse the trend. According to the findings of a major European study, permanent grassland can in the long term bind 500 kilograms of carbon (or 1 850 kilo in CO<sub>2</sub> equivalents) per hectare and year.<sup>4</sup>

D. Keeling began measuring concentrations of carbon dioxide (CO<sub>2</sub>) in the atmosphere in an observatory on Mauna Loa, Hawaii, in 1958.

**Sustainable development: a definition**

Environmental Studies is a branch of science that focuses on the relationships within the natural environment and how natural systems relate to human activity. Increasingly often, environmental scientists are warning of the damage now being done to the environment, the irreversible impacts on biodiversity, and impending climate change. The earliest warnings were raised in the 1960s by scientists and writers like Rachel Carson with her landmark book, *Silent Spring*, and here in our part of the world, Hans Palmstierna<sup>6</sup> and Georg Borgström in Sweden and G. Henrik von Wright<sup>7</sup> in Finland. The work of these and others led to the first international conference on the environment to be held under the auspices of the UN, in Stockholm in 1972, where a number of supra-national organs in the area of environmental protection were formed. For my part, I stood outside the conference hall in a stand, trying to sell my organic and biodynamic vegetables – but the delegates was to hurry and past without notice.

In 1987, then-Prime Minister of Norway Gro Harlem Brundtland published a report entitled *Our Common Future*<sup>8</sup>, in which the term, ‘sustainable development’ is defined as follows: “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*”. The international Conference on Environment and Development held in Rio de Janeiro in 1992

<sup>2</sup> Hans Furuhaugen. 1974. Vårt dagliga bröd. Om folkförsörjningen under antiken [Our daily bread: On the supply of food in Classical Antiquity]. Folkfronts Förlag.

<sup>3</sup> FAO, Mediacycenter. 2011. Opening the door to carbon crediting, www.fao.org (27 September). Carbon storage. World Resource Institute, www.wri.org/publication/content/8272 .

<sup>4</sup> FAO, Mediacycenter 27 september 2011. Opening the door to carbon crediting, www.fao.org. Carbon Storage. World resource Institute. www.wri.org/publication/content/8272

<sup>5</sup> Tilman, D., Cassman, Matson, K., Naylor, R. and Polasky, R. 2002. Agricultural sustainability and intensive production practices. NATURE | VOL 418 | 8 AUGUST 2002 | www.nature.com/nature.

led to the first global program of action to achieve sustainable development of the planet with well-defined objectives. The program of action, known as *Agenda 21*<sup>9</sup>, with its 40 chapters was adopted, and work toward important international conventions on climate change, biodiversity and desertification got under way. Ten years later, a follow-up conference was held in Johannesburg, South Africa – a global summit on sustainable development in all its dimensions: social, economic and environmental. Very important will now be the new conference, Rio + 20, in June 2012. The Baltic Sea project, BERAS-implementation, which is presented later in this book, has been invited for presentation there.

### 2° C – will it be enough?

Binding targets for national reductions in climate-altering emissions were codified in the Kyoto Protocol,<sup>10</sup> formulated in negotiations at the UN climate summit held in 1997 pursuant to a decision taken at the UNCED Conference in Rio. The Protocol took effect, however, in February 2005, when Russia joined the signatories. According to the terms agreed, the signatory industrialized countries have made a commitment to reduce their emissions by a total of 5.2 per cent (calculated on the basis of the country's emissions in 1990) in the period 2008-2012. Sir Nicholas Stern, former Chief Economist for the World Bank, awakened the world to the issue of climate change in 2006, when he published a report on the economic consequences of climate change and the costs of delaying our response to the challenges it posed, expressed in dollars and cents.<sup>11</sup> Then attached to the Cabinet Office, he was commissioned to do the study by then-Prime Minister Tony Blair. Sir Nicholas estimated the damage due to climate change to amount to between 5 and 20 per cent of the global GNP in 2050. His report also pointed out that a disproportionate share of the costs would be borne by nations in the poorer parts of the world, although they contributed least to the problem.\*

The UN Intergovernmental Panel on Climate Change (IPCC)<sup>12</sup> has subsequently deemed the situation to be even more critical than when

<sup>6</sup> Palmstierna, H. 1968. Plundring, Svält och Förgiftning [Pillage, hunger and pollution]. Ordfronts förlag.

<sup>7</sup> Georg Henric von Wright 1993. Myten om framsteget. Boniers Förlag.

<sup>8</sup> Brundtland, G.H. 1987 Our Common Future. Oxford University Press. Oxford

<sup>9</sup> United Nations, 1992. Earth Summit. Agenda 21: Programme of Action for Sustainable Development. The final text of agreements negotiated by Governments at the United Nations Conference on Environment and

<sup>10</sup> The Kyoto Protocol to the United Nations Framework Convention on Climate Change adopted 11 december 1997 at a climate summit conference held in Kyoto, Japan.

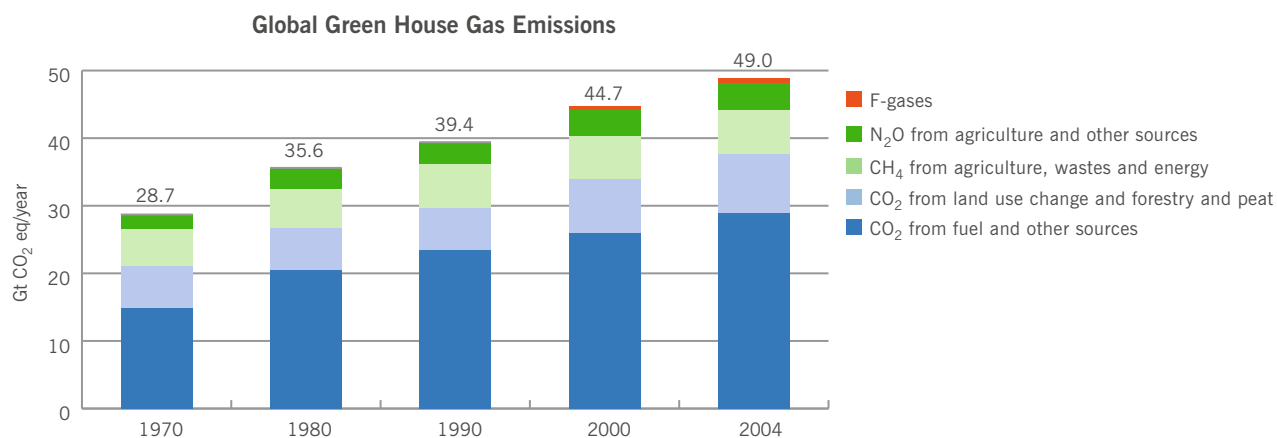
\* (See European Parliament resolution on the outcome of the Copenhagen Conference on Climate Change (COP 15). <http://www.europarl.europa.eu/sides>

the Protocol was drafted. Use of fossil energy in countries like China has increased more rapidly than was foreseen. Secondly, many experts now worry that the target of a maximum load of 550 ppm of greenhouse gases (calculated in terms of CO<sub>2</sub> equivalents) in the atmosphere will not be adequate to prevent a global rise in atmospheric temperature beyond +2° C (in relation to temperatures in the pre-industrial era). Attainment of that goal now appears to require a maximum load of 400-420 ppm – the level where we are today. What is more, acceptance of a rise in temperature of 2° C is being called into question by researchers who believe that even such a rise will result in unacceptable negative impacts on societies and ecosystems. In reality, we have yet to see any reductions in global emissions of greenhouse gases; on the contrary, they continue to increase.<sup>13</sup> At this writing, the climate issue appears to have been eclipsed by the current financial crisis in Europe. The relationship between depleting natural resources – with extensive environmental damage, especially in the poorest countries – and the current economic crisis in wealthier countries having a high level of material consumption, deserves closer examination.

Figure 7. Global emissions of greenhouse gases by source. (Source: IPCC 2007) Emissions have doubled in the past 35 years. In addition to emissions of CO<sub>2</sub>, emissions of methane and nitrous oxide (“laughing gas”), primarily from agriculture, contribute significantly to the greenhouse effect. CO<sub>2</sub> makes up 60 per cent of total greenhouse gas emissions and amounts to a total of 8 billion tons of carbon, or 1.2 tons per capita and year. Emissions in Sweden are 1.6 tons per capita; in Norway, Denmark and Finland emissions are more than double the global average.

### Self-intensifying processes

There are scientists who consider the risk of climate change exaggerated. On the other hand, others are convinced that climate change may proceed much faster than we have believed possible, as a result of self-intensifying mechanisms. CO<sub>2</sub> emissions from human activity interact with and influence both marine and many terrestrial ecosystems. Up to now, the seas have absorbed roughly one-half billion tons carbon of the increase in CO<sub>2</sub> emissions, but this buffer capacity weakens as the



<sup>11</sup> Stern, N. 2006. “Stern Review on The Economics of Climate Change (pre-publication edition). Executive Summary”. HM Treasury, London

<sup>13</sup> The IPCC, a panel consisting of climate experts from 150 countries, was established in 1988 through a joint undertaking of the World Meteorological Organization and the United Nations Environment Programme.

seas become more acidic (a consequence of CO<sub>2</sub> absorption). Thus, a progressively greater share of the emissions remains in the atmosphere, and the climate impact is intensified. Arctic ice has also been shown to melt faster than anticipated, which starts other self-intensifying processes, such as less area in permafrost.

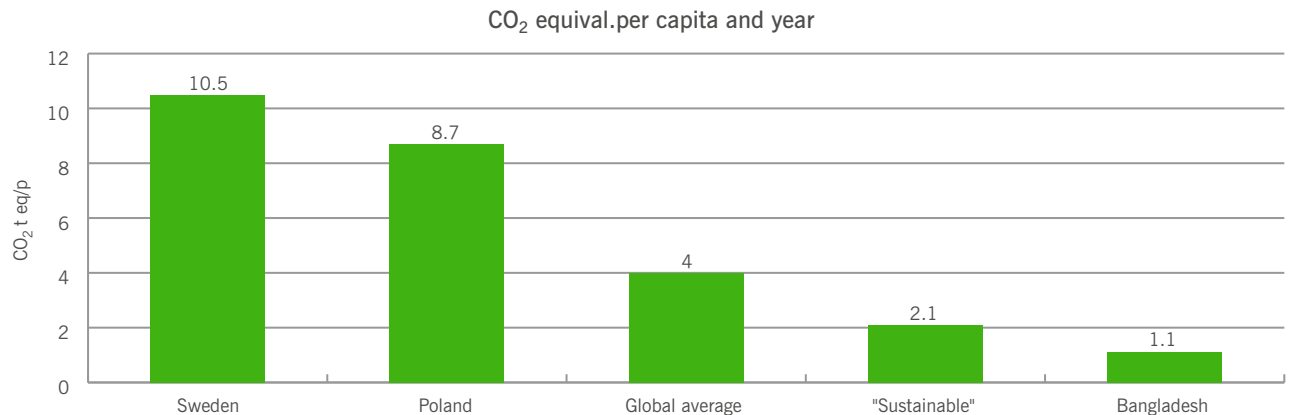
Six greenhouse gases and classes of gases are considered in the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>). Other important climate-altering gases are steam and ozone.

Greenhouse gases impair the reflection of solar heat back into space, which results in a warmer climate. The unit 'CO<sub>2</sub> equivalent' is used to make it possible to calculate the cumulative effect of all greenhouse gas emissions. Sometimes emissions are expressed not in the amount of CO<sub>2</sub>, but in terms of the amount of carbon. One kilo of carbon in the form of carbon dioxide (CO<sub>2</sub>) equals 3.67 kg of CO<sub>2</sub>.

As early as 1989, a framework describing the preconditions for ecologically sustainable life on Earth was formulated by Swedish oncologist and environmentalist, Dr. Karl Henrik Robèrt in dialogue with 50 researchers in many different disciplines in a number of countries around the world. Their work resulted in four "System conditions", a platform that has won acceptance in many quarters. The conditions are that

1. nature is not subject to systematically increasing concentrations of substances extracted from the Earth's crust;
2. nature is not subject to systematically increasing concentrations of substances produced as a byproduct of society;
3. nature is not subject to systematically increasing degradation by physical means;
4. people are not subject to conditions that systematically undermine their capacity to meet their needs.<sup>14</sup>

Figure 8. Per capita emissions of greenhouse gases from human activities relating to consumption (net effect with attention to import and export), expressed as CO<sub>2</sub> equivalents, in selected countries, the global average, and the level considered sustainable, given a rise in temperature of 2° C. To achieve sustainability, the average Swede will have to reduce his/her emissions by 80 per cent. Source: Carbon footprint of nations. Environmental Science & Technology 43:16 (2009).



<sup>13</sup> See European Parliament resolution on the outcome of the Copenhagen Conference on Climate Change (COP 15). <http://www.europarl.europa.eu/sides/getDoc.do?type=MOTION&reference=B7-2010-0070&language=EN>



What is different these past 100 years is that human activity has begun to affect the dynamic processes of the ecosystems, globally

The not-for-profit organizations that have been formed around Dr. Robèrt's work carry on dialogues with individuals and, not least, companies about the steps they can take to achieve sustainability in accordance with these basic conditions.

### Planetary boundaries

For the past 10 000 years our planet's self-regulating systems have ensured that variations in the Earth's atmospheric temperature, water reserves, precipitation and flows of key biological substances have remained reasonably stable within the rather narrow margins within which life is possible. Historically, even minor changes in mean temperature and precipitation have given rise to crises and mass migrations. What is different these past 100 years is that human activity has begun to affect the dynamic processes of the ecosystems, globally.

In 2009, a group of 28 internationally renowned researchers, led by Johan Rockström of the Stockholm Resilience Centre and Will Steffen of the Climate Change Institute at the Australian National University (Canberra), published an article in *Nature* that proposed a comprehensive tool by which we can determine what we can do and what we must avoid doing, so as not to pass the limits of what our planet can withstand. Only if we remain within those limits can the self-regulating systems we have relied on continue to function.<sup>15</sup> Threshold values for nine biochemical processes initiated by human activity were defined: climate-changing emissions to the atmosphere, depletion of the ozone layer, changes in land use (conversion to cultivation), freshwater use, loss of biodiversity, ocean acidification, leakage of nitrogen and phosphorus to land and sea, aerosols in the atmosphere, and toxic chemical pollution. In three of the areas – climate-changing emissions, nitrogen and phosphorus loads to the environment, and loss of biodiversity – we may already have exceeded the limit to the extent that we have diminished our prospects of survival, the authors fear.

Johan Rockström recently published an article in Sweden's leading daily newspaper in which he exhorted Swedish politicians and policy-makers:

*"It is imperative that we reform the world's energy systems and the way we do agriculture. Otherwise, the future development of mankind is in jeopardy. We have reached a point where we have exceeded several boundaries for the capacity of the Earth to regenerate social and economic development in the longer term. We face not only a climate*

<sup>14</sup> <http://www.thenaturalstep.org/en/the-system-conditions>

<sup>15</sup> Rockström, J et al. (2009) A safe operating space for humanity. *Nature* 461:472-475.

See also: [http://en.wikipedia.org/wiki/Planetary\\_boundaries#The\\_nine\\_boundaries](http://en.wikipedia.org/wiki/Planetary_boundaries#The_nine_boundaries)

*crisis, but a global ecosystems crisis. The situation calls for renewed collaboration on a global scale.*"<sup>16</sup>

Rockström's article did not discuss in what ways agriculture needs to be reformed. So, in response to his appeal, I wrote an article, entitled: "How to eliminate the climate impacts of our food," which was published in the internet edition of the paper a couple of days later.<sup>17</sup> The theme in that article is what a good part of this book is about.

### Fossil energy use must decrease by 80 per cent

We have to restore the balance between consumption and recycling of natural resources. The energy source of the future is the Sun; we already benefit from its energy thanks to processes in plant life, supplemented with technical solutions that make use of solar energy directly, alongside energy produced by wind and water. Ultimately, the task before us is to reform all our industrial activity and the energy- and resource-wasting lifestyles that have developed in Europe, North America and other industrialized regions over the course of the twentieth century. Furthermore, we have to bring the processes of reform down to the local level.

We in northern Europe are among the 20 per cent of the world's population who consume 80 per cent of the planet's most important resources; we also are responsible for a corresponding share of global environmental pollution. If the majority of the world's climate scientists are right, we have only a few decades in which to complete the conversion to renewable energy sources. If we are to confine the rise in temperature to a maximum of 2° C, the IPCC experts say, global use of fossil energy has to be reduced by something like 80 per cent in the span of the next thirty years. How we farm and what we eat play key roles in this connection (Figure 5).

In addition to rising atmospheric emissions of stored fossil and organically bound carbon, our disruptions of the nitrogen cycle are also crucially important to the global environment of the future. Too much nitrogen leads to increasing emissions of the potent climate-altering agent, 'laughing gas' (N<sub>2</sub>O) and increasing nitrate content in water that is already poisoning our drinking water in intensively farmed regions. Emissions of nitrogen and phosphorus compounds lead to eutrophication of rivers, lakes and the sea.

In order to ensure that the Earth will be habitable for generations to come, we must see to it that the essential basis for our existence, arable soil, is tended in ways that restore and preserve its fertility. At

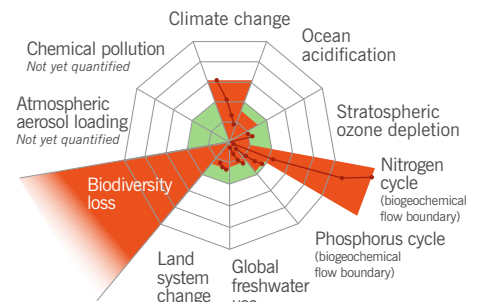


Figure 9 Planetary boundaries, Johan Rockström: Source: Stockholm Resilience Centre (recently published in *Nature*).

<sup>16</sup> Rockström, J (2011) 2011 blir ett viktigt år för en global framtid [2011 will be an important year for our global future]. Dagens Nyheter January 23.

<sup>17</sup> Granstedt, A (2011) Så elimineras matens belastning på klimatet [How to eliminate the climate impacts of our food]. Dagens Nyheter (internet edition) January 26.



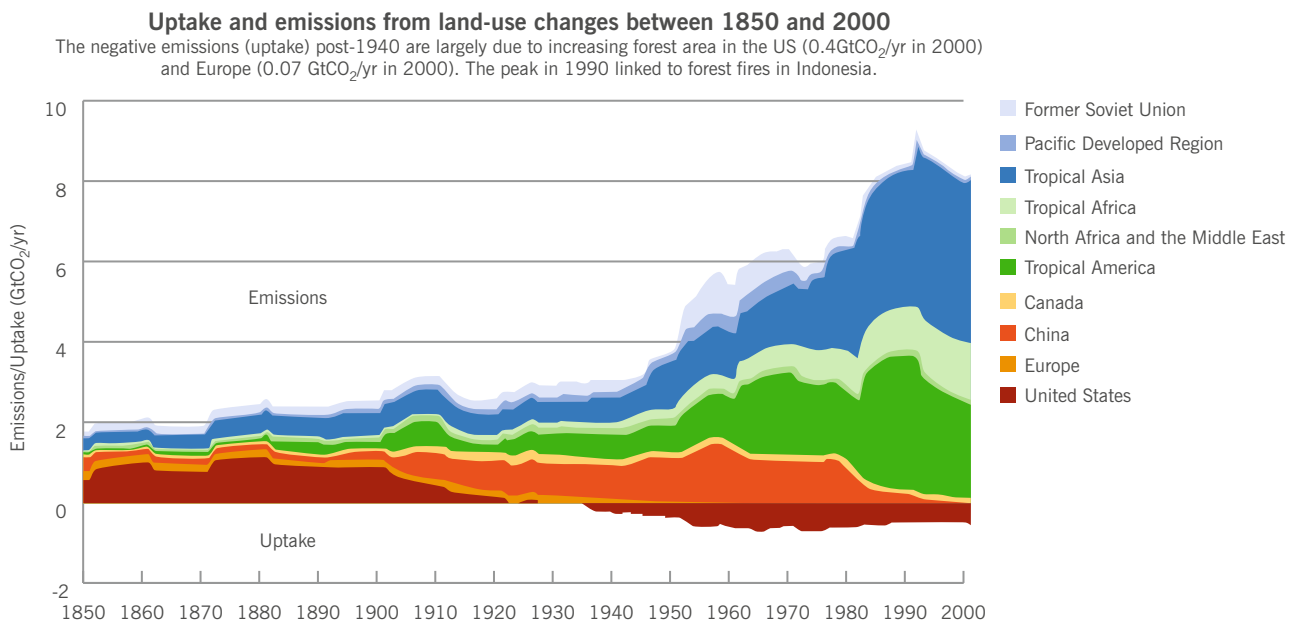
present we are doing the opposite. Something on the order of one-fifth of the annual increase in atmospheric carbon is attributable to the fact that organic substance in the form of forests and arable land is declining (Figure 6). We must learn once again how to base our existence on the regenerative powers of the plant world, making proper use of the soil and plants through the right kind of farming and forestry practices. The green resources that take carbon out of the atmosphere and bind it are shrinking as a result of our abuses of our planet, all the while that same planet has to support a rapidly growing population.

### The living earth

Arable soil is the product of millennial processes involving organic and inorganic materia in interplay with the underlying bedrock. The topsoil consists of a fine mix of minerals from weathered bedrock and organic substances deriving from the animal and vegetable kingdoms.

Even on the face of bare rock we find what would seem to be the simplest of green organisms, lichen. Lichen are fungi that live in symbiosis with a photosynthesizing microorganism – algae or cyanobacteria – and can fix atmospheric nitrogen. Thanks to their symbiotic relations these organisms have been able to stretch the limits of survival. They get their energy from the Sun and their sustenance from air and water. They generate carbohydrates and proteins to sustain their vital functions, and they start weathering the surface of the stone. During millions of years, stone, gravel and sediment have developed into soil

Figure 10. An estimated 15-20 per cent of the annual increase in atmospheric CO<sub>2</sub> may be attributed to deforestation and erosion and destruction of humus. The global humus capital and areas covered by photosynthesizing vegetation are shrinking. Source: Carbon Dioxide Information Analysis Centre, CDIAC, 2002.



that supports the growth of more advanced plants and communities of plants.

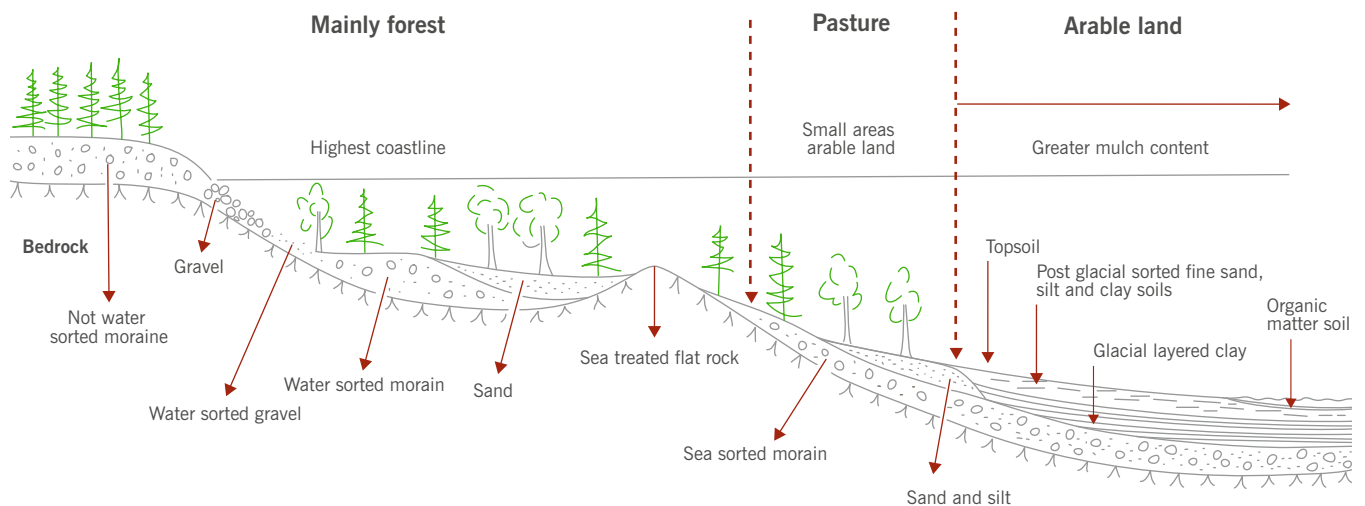
### Mineral soil

Pure mineral soil consists solely of weathered stone. The bedrock is constantly decomposing under the combined impact of air, water and changes in temperature on the one hand, and the activity of living organisms on the other. Some mineral substances are freed in the form of water-soluble salts. It has been calculated that after 70 million years, all the stone in the Earth's crust would have been decomposed and lie on the sea bed, were it not for countervailing processes of various kinds. The crust of the Earth is in constant motion. Continents drift to and fro, albeit extremely slowly, gauged in human terms. New mountains rise up, while sea bed sediments may be drawn down into the underlying magma. All in one gigantic geological cycle. Here in northern Europe we have young soils, the mineral content of which originated in the most recent period of continental glaciation: through the action of glaciers, the great flooding rivers formed as the ice-fields melted, and seas of ice, where ground fractions of stone formed layers that were subsequently raised above the surface as the crust responded to the loss of ice cover.

### Fine distribution is the key

The degree of fineness is an important factor for soil characteristics. Sandy soil is "coarse". The large size of the particles means that the sand does not

Figure 11. The soil types form layers under what was formerly the highest coastline. Topography and the distance from former mouths of glacial rivers determine the configuration. Fine-grain glacial clays were deposited furthest out on the clay plains, whereas sand and gravel formed sediments gradually as the flow of runoff subsided. With the rising of the land mass over the millennia, the sediment from former coastlines underwent wave action and successive redeposition, and postglacial sediment now covers the former sea bed. It is possible to study the ongoing development of fertile soil in coastal meadows and the continuing rise of the land after the most recent period of glaciation.





In geological terms, most of the Baltic Sea region rests on a slightly vaulted geological formation known as the Baltic shield. In the north it consists of bedrock; to the south a complex of moraine deposited as the continental ice pack retreated

hold water or nutrients very well. At the opposite end of the scale we have clays, whose constituent particles are small enough – less than a couple of microns (thousandths of a millimeter) in diameter – to stick together in aggregates, producing a fine soil structure. Clay particles also have an exceptionally good capacity to retain nutrients and water. Consequently, clay soils are more resistant to leaching of nutrients, which otherwise is a widespread problem, given Nordic climatic conditions.

The most recent period of continental glaciation has decisively influenced the nature of soil in the Baltic Sea region today. The ice crushed rock; gravel and stones were transported by ice and water. When the ice pack retreated some 10 000 years ago, the Earth's crust began to rise slowly out of the sea, and more and more land surfaced. The processes leading to fertile soil and vegetation could start. The sea level peaked around 8000 BC. In both Sweden and Finland it is possible to observe this former highest coastline. Above it, we find unsorted moraine that melting glacial ice left behind; below it, we find areas with layers of soil formed by the water in the larger lakes and lake systems in central regions of both countries. As the shorelines moved, wave action rearranged the layers.

Two types of soil may be distinguished: nutrient-poor sandy and gravelly soils 'rinsed out' by wave action, and layers of more fine-grained sandy soil, silt and clay that accumulated on the flatter regions of former sea beds. These latter sediments supported a rich and varied natural vegetation, which provided the basis for cultivation today. The land mass continues to rise, but at a successively slower rate in most of Sweden and Finland; the effects of this process are still observed. New arable land is still being formed in the northern reaches of the Baltic Sea area, whereas an opposite process is taking place to the south. The fertility of the soil depends in large part on the minerals the soil is made of.

#### **More acidic soils to the north**

In geological terms, most of the Baltic Sea region rests on a slightly vaulted geological formation known as the Baltic shield. In the north it consists of bedrock; to the south a complex of moraine deposited as the continental ice pack retreated. A line on the map drawn from the northern tip of the Jutland peninsula in Denmark eastward to the northernmost point on the shore of Lake Ladoga in Russia describes the southern boundary of the granitic shield. South of the line we find younger kinds of rock like limestone, sandstone and shale; the area north of the line is characterized by the granite of the bedrock and the more acidic soils associated with granite. We also find areas that bear the scars of the continental glacier: patches of bare granite and granite cliffs that rise above the surrounding landscape. In areas of clay in eastern central Sweden (approx. lat. 58-60° N) we do find some areas of

sedimentary limestone from the limestone fundament that once covered the area to the northeast. There are also limestone deposits in western Sweden around the lakes, Siljan (61° N) and Storsjön (63° N), which have produced fertile land in these areas, as well.

### Humus, a millennium in the making

The organic part of soil, humus, is made up of decaying plant material that is broken down, processed and converted by small animals, worms, fungi and bacteria that live in the soil (known collectively as *edaphon*). Thoroughly converted humus, called mulch, makes up the main part of the organic substance in cropland. The chemical composition of humus is a function of the chemistry of the original plant material. On average, one hectare of cropland having a mulch content of 3 per cent, assuming a topsoil layer of 20 cm, contains about 90 tons of organic material (9 kg/m<sup>2</sup>), roughly 5 tons of which (0,5 kg/m<sup>2</sup>) may consist of living organisms, one-fifth of which is the vitally important earthworm. The organic substance in the soil contains all the elements these living organisms need. The topsoil of the hectare in question may contain 50 tons of carbon (5 kg/m<sup>2</sup>), 5 tons of nitrogen (0.5 kg/m<sup>2</sup>) and one ton of phosphorus (0.1 kg/m<sup>2</sup>). In addition there are a number of elements that are both organically and chemically bound, like sulphur, lime and vital trace minerals. Some of the humus in the soil may be more than one-thousand years old. Humus in the soil is subject to microbial decomposition by bacteria and fungi, which releases important nutrients. This constant decomposition has to be balanced by a sufficient supply of new decaying plant material. Pure mulch soils have their origins in former bogs and wetlands.

Organic material in various stages of decay and materia produced by soil organisms combine to form capacity to bind nutrients in the soil and give the soil the porosity that is needed to give plants and organisms a proper balance between hard particles, moisture and air, which is so important to them. On clay soils humus particles, proteins and mineral particles of clay aggregate to provide particularly favorable conditions for plant growth. Whereas humus is an important component in the soil, giving it its physical and chemical characteristics, humus is also, in itself, a source of nutrients for plants and soil organisms.very large molecules, so-called humus substances. Particles of mull have an extraordinary capacity to bind nutrients in the soil and give the soil the porosity that is needed to give plants and organisms a proper balance between hard particles, moisture and air, which is so important to them. On clay soils humus particles and mineral particles of clay aggregate to provide particularly favorable conditions for plant growth.



90 tons of organic material (9 kg/m<sup>2</sup>), roughly 5 tons of which (0,5 kg/m<sup>2</sup>) may consist of living organisms, one-fifth of which is the vitally important earthworm

### Where organic processes meet dead material

In natural, uncultivated soil the uppermost layer is pure humus, and under it there is what is generally called mineral soil. In cultivated soil there is a recurrent mixing of the soil to a depth of about 20 cm, i.e., as deep as ploughs reach. In soil, organic material from living plants comes into contact with non-living mineral. This is accomplished through the decomposing action performed by organisms that live in the soil. In good soil, as much as 50 per cent of the organic substance may be integrated with particles of clay to form so-called clay-humic complexes. Such integration facilitates the formation of aggregates and slows the process of humus decomposition.

Bacteria and fungi as well as larger organisms like annelid worms (of which the earthworm is the most widely known species) are especially important in the development of fertile soil. Worms bring the remains of decaying leaves underground, and, together with bacteria and the mineral particles in their intestines make specific contributions to the soil structure and the metabolism of different kinds of organic material. There is also an intimate interplay between plants and organisms in the soil. Different plants' roots reach down to different depths in the soil, depending on the species and characteristics of the soil. Roots exude energy-rich substances that stimulate microorganisms, which in turn help to free nutrients, enriching the supply of plant nutrients.

### Fertile soil is self-regulating

The interplay of living organisms in the soil may be likened to the inte-

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Figure 12. A shallow inlet on Järna Sound, just south of the point where Lake Mälaren empties into the Baltic Sea (at about 59° N). Sweden's land mass is still rising, albeit slowly. At this latitude it is rising at a rate of about 3 mm per annum. The first vegetation on the shore contributes the first humus, which may later become fertile cropland. Above the shoreline in the picture we see traces of agriculture that was practiced here as early as the bronze age (1500–500 BC).

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Photo Artur Granstedt

reaction of cells and organs in living organisms of more advanced species. Fertile soil is, within certain bounds, self-regulating vis-à-vis external influences. The fertility of soil depends on the organisms and organic material that is added to it by plants and animals, but also the nutritive content in the raw materials that make up the mineral soil. Only lesser shares of the land area of Sweden and Finland have characteristics that are suitable for growing crops. Countries like Denmark, Poland, parts of Germany, Estonia and Latvia have considerably greater shares of arable land. The climate and topography – the landscape, hills, mountains, valleys, etc. – are other important factors. The land has to be dry enough so that Spring runoff and precipitation quickly drains away; at the same time it has to be moist enough to support plant life. It must be free of impediments to cultivation in the form of stone blocks and boulders. Mountains and alps and too cold a climate in the far north of the Baltic region define the bounds of cultivation. Some soils formed of younger rocks are very fertile, as are soils rich in chalk. The mulch content is another important factor for fertility. Mulch reduces leaching of nutrients, which is particularly important in sandy areas. High mulch content also enhances soil fertility and is especially important in soil that has little clay. Fertile soil must be able to maintain a favorable balance between air and water and offer the nutrients that plants and soil organisms require. The soil must also be porous enough so that roots and even earthworms are able to make their way through it.

### **Tilled soil, an ecosystem**

In young ecosystems the number of species and the amount of organic material increase year by year. The first to colonize a piece of land are generally simpler organisms like algae and lichen. Gradually, plants and animals join them. Depending on prevailing conditions (climate, chemical composition and so forth), a selection of specifically adapted plant and animal species is attracted to the land – forming a biotope. In mature ecosystems we find a balance of different groups of inhabitants.

A planted field is in principle a young ecosystem, the survival of which depends on human labor. If left unattended, cropland in northern Europe will be invaded by shrubs and sapling trees; ultimately, it will become forest. We find many examples of abandoned cropland in Estonia, Latvia and Lithuania, but in Sweden and Finland, as well – particularly less productive land. In such areas grazing is a good alternative in order to deter colonization by shrubs.

Like natural ecosystems cropland, too, can attain a higher degree of ecological stability. The greater the variation and number of species, the greater the stability, with less risk of imbalances, due, for example, to invasions of destructive pests.



If left unattended, cropland in northern Europe will be invaded by shrubs and sapling trees



## IN A GLOBAL PERSPECTIVE ARABLE LAND AND THE PLANET'S FOOD NEEDS

Only about one-tenth of the ice-free land mass on planet Earth supports agriculture; what is more, that area is shrinking because the soil is being used in ways that deplete mulch or nutrients, increase salinity, or cause the loss of fertile soil through erosion or desertification. This has happened throughout human history – but history also shows that negative processes can be reversed.

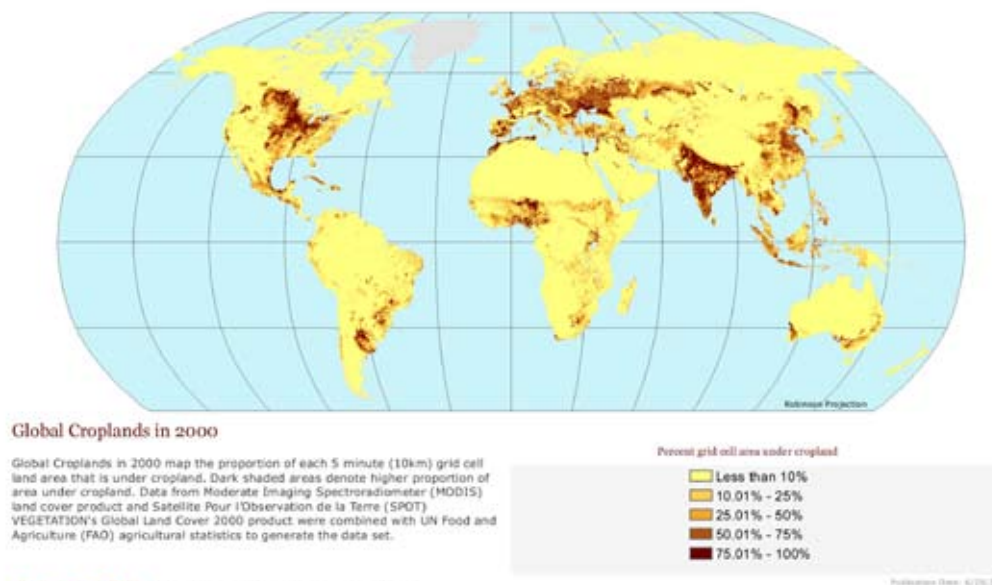
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Figure 13. Most of the world's cultivated land is located in the red areas of the map. It represents only 10 per cent of the ice-free land mass. These 1.5 billion hectares today (late 2011) provide food for 7 billion people. Source: Ramankutty, N et. al. (2010) *Global Agricultural Lands: Croplands*. Data distributed by the NASA Socioeconomic Data and Applications Center (SEDAC). <http://sedac.ciesin.columbia.edu/es/aglands.html>.

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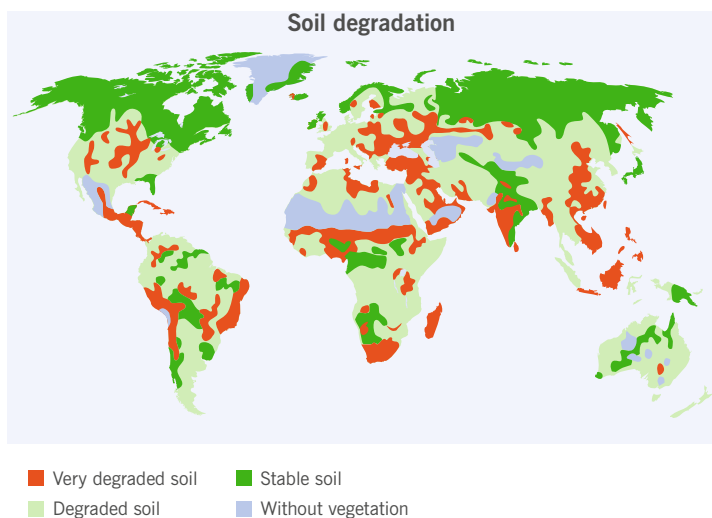
Most tropical regions of the world do not have enough water. Access to water also sets the limits on how much land can be irrigated.

The potential gains of cultivating land currently covered with rainforest are limited. Too much rainforest has already been cut. Where the land has been cleared, it is subjected to a chemical-intensive, specialized kind of farming. Whereas previous, less harsh slash-and-burn methods allowed reforestation, modern large-scale land clearance practices lead to land degradation and erosion. Current deforestation threatens to accelerate the greenhouse effect and destroy the subsistence of millions of people. We have seen many examples of how deforestation worsens the consequences of natural catastrophes, causing acute suffering for millions of people.



Irrigated agriculture is characteristic of East Asia, with rice the staple crop – corresponding to wheat and rye in our part of the world.

Large areas of the planet are mountains or dry plains, which afford the possibility of some extensive grazing. Too heavy grazing damages the land and causes deserts to spread. Only 11 per cent of the total land mass on the planet supports agriculture. An additional 24 per cent supports more or less extensive grazing; 31 per cent is forested. All told, cultivated land amounts to 1.4 billion hectares, roughly half of which is currently used to produce cereal products. Together, erosion, increasing salinity and the expansion of deserts have put an end to the net growth of cultivated acreage, despite the fact that new land is still being exploited for agricultural production. Great expanses of grazing land have been turned into desert or semi-desert. Cultivation of new lands in itself poses a threat to remaining forests, which are vital to the maintenance of the planet's climatic system, biocycles and biodiversity. A study undertaken under the auspices of the UN Food and Agriculture Organization (FAO) over a twenty-year period indicates that land degradation – defined as chronic reduction of the function and productive capacity – is on the increase in many parts of the world. According to the data, 20 per cent of the world's cultivated acreage, 30 per cent of all forest and 10 per cent of all pasturage has been degraded. The study estimated that 1.5 billion people, or nearly one-quarter of the planet's population, are directly dependent on the land that is in the process of degradation. Measures



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*Figure 14. Deforestation and farming methods that break down humus – like, for example, too high a share of plowed crop land in the crop rotation – lead to declines in the amount of mulch in the soil and thus to land degradation, which in turn has negative impacts on both the climate and global water resources. Even in the Baltic Sea region soil may be degraded in areas of intensive grain production.*

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to stop this degradation and instead improve the fertility of these soils should be accorded the highest priority to ensure food security for the poorest people in the world.

One threat to the global food supply that has yet fully to be given the attention it deserves is the ongoing change in the planet's climate and accompanying alterations in weather patterns in different parts of the world. Arid parts of the world risk becoming drier, which implies a threat of poorer harvests. Meanwhile, wetter parts of the world may receive too much precipitation. At the same time, more precipitation, combined with warmer temperatures may in fact improve growing conditions here in the Baltic Sea region.<sup>18</sup> Many others, however, face the threat of losing their farmland to a rising sea level. More than 275 million people in the world today raise crops on land that is less than five meters above sea level. Melting ice at high altitudes and in polar regions like Greenland and western Antarctica, and thermal expansion of sea water are two principal factors contributing to the rise.

Today (spring 2012), the world's croplands have more than 7 billion mouths to feed. By 2050, the population of the world is expected to have grown by 2.1 billion people to a total of 9.1 billion, according to a review of world population data published by the United Nations.<sup>19</sup> About 80 per cent of the expected increase in population will take place in already overcrowded parts of the world. Today, the average area of cropland per capita in the world is only two-tenths of a hectare (2 000 m<sup>2</sup>). We in Sweden use twice the average, 0.4 ha, per capita when food and feed imports are included. In Asia today, the per capita area of cropland is 0.19 ha; there are also countries where the figure is less than 0.1 ha. It is in these latter areas that a good share of the new billions of world citizens will be born. The amount of cropland per capita is shrinking faster here than anywhere else.

### **Migration**

Food shortages in the world today are mainly due to an uneven distribution of resources and to social injustice. People cannot afford to pay for the food that exists. The people of industrialized countries consume a much greater share of the world's food resources than the average person. They do this through food imports and a heavier consumption of meat and dairy products, the production of which largely depends on imported feed from poorer parts of the world. These are in many cases crops that might otherwise be used as primary food products in the countries where they are produced. Most imported feed comes from Latin America and southern Asia.

<sup>18</sup> IPCC, 2007. Climate Change 2007, Working Group 1: The Science of Climate Change, FAQ 3.2

If we look at the overall capacity to “feed the world” in a longer perspective and in relation to population growth, we find that there is no surplus of food, nor is there a surplus of arable land. Both international trade in food products and migration will most probably be needed in future years to distribute the food there is more evenly. A trend toward more consumption of vegetables, fruit and seeds is likely to be necessary in order for there to be enough food for all. The current trends toward increased consumption of meat, both here in Europe and in cultures that have previously had essentially vegetable-based diets, are steps away from, rather than toward, sustainable consumption of food.

### **900 times more**

Before human beings began farming, they lived on the results of hunting wild animals, fishing and gathering the edible plants, fruits, seeds and nuts that Nature provided. It has been calculated that thirteen to fifteen thousand years ago planet Earth was able to support a population of about about eight million. Today, the planet feeds almost 900 times as many people.

Gradually, hunting of animals changed, in a variety of ways, into herding and keeping of domesticated animals. Crop cultivation replaced earlier gathering of plants and plant products. And, over time, we have learned to improve varieties, and develop new varieties of plants and breeds of animals. Once humans began to raise grain crops, it became possible to store and transport food supplies, which made it possible for people to settle in one place rather than wander. Grains also opened up the possibility to trade in food, which made it possible to support urban populations.

Early farming cultures used deposits of nutrients that had been created by natural ecosystems. The deposits were used up through slash-and-burn and semi-nomadic agricultural systems. These methods are still practiced in some parts of the world, and if applied intensively, they lead to rapid depletion of natural resources.

### **Life-giving alluvial silt**

The first major cultures of the historic period developed in alluvial flood plains and deltas, where rivers regularly inundated the land with nutrient-rich silt. These agricultural cultures were founded 10 000 to 5 000 years ago. The most widely known sites are the Indus plain in India, the Mesopotamian culture of Babylon around the Euphrates and Tigris, and the Egyptian culture along the Nile. These civilizations were possible thanks to an ecological balance between cultivation and the natural ecosystems that supplied the land with water, nutrients and an



The people of industrialized countries consume a much greater share of the world's food resources than the average person

<sup>19</sup> UN, Department of Economic and Social Affairs, Population Division (2005) <http://www.un.org/esa/population/publications/WPP2004> .



History provides examples of how misuse and abuse of natural resources can destroy the very basis of all culture, arable land. But it also offers examples of the opposite.

appropriate climate. The earliest known Mediterranean culture, that developed by the Etruscans in present-day Italy, was a form of crop rotation agriculture that involved cautious exploitation of the forested land.

The rise and fall of great cultures have often been a consequence of access to food. When productivity of the cultivated soil declined, it led to hunger, short-term predatory exploitation and, ultimately, to mass starvation and failure of the culture as a whole. The causes of decline have varied. Where sophisticated irrigation systems had been developed, the decline in harvests might be the result of salinization or waterlogging. Records inscribed on clay tablets relate how Mesopotamia foundered because of declining harvests and chronic food shortages.<sup>20</sup> The Roman Empire fell after deforestation and over-grazing in the Mediterranean region had led to loss of fertile cropland and food shortages. Today, we see deserts expand over what was once cropland as a result of over-use of the land.

History provides examples of how misuse and abuse of natural resources can destroy the very basis of all culture, arable land. But it also offers examples of the opposite, of how we can increase the capacity of land to support us.

<sup>20</sup> Furuhagen, H (1978) Bröd och skådespel [Bread and spectacle]. Stockholm: Norstedts.

## FARMING IN THE BALTIC SEA REGION A BRIEF HISTORY WITH EXAMPLES FROM SWEDEN FROM SLASH-AND-BURN TO 'ANIMAL FACTORI

**The production of meat, dairy products and grains multiplied – long before there were synthetic fertilizers or pesticides. How could it be done?**

Fire helped to clear land for both cultivation and meadows. After the land was cleared, hoe and wooden ploughs worked the soil.

Through cultivation we transform Nature into a cultural landscape with open fields, grazed meadows and so forth. Once we sink a hoe, spade or plough into the soil, we begin to change the soil itself. Greater access to air, together with warmth and moisture, increases microbes' respiration and the rate of their metabolism of organic material. The freeing of organically bound nitrogen and other nutrients increases, and more nitrogen, phosphorus and other nutrients becomes available to plants. Faster growth leads to greater biomass production. The increased decomposition of the organic biomass in soil needs to be compensated through recycling of organic biomass. When this is done, the interchange between land and vegetation is intensified, while the layer of topsoil becomes deeper when it is worked with hoes and other implements.

Growing crops keeps the soil free of perennial weeds: the grass, herbs, shrubs and trees that succeed one another if the land is left untilled in a young (from an ecological point of view) phase of development, when biological turnover and productivity are both high. At the same time, the system is less diverse and, in the event of monocultures, with only one or a very few crops that succeed one another, its vulnerability increases.

Slash-and-burn farming techniques were used even in the Stone Age here in the Nordic region. Harvests were good in the first years. The ashy soil produced by burning over the land was rich in nutrients in forms readily accessible to the plants. But because no organic biomass was returned to the soil in the form of manure or plant material, the soil quickly lost both organic biomass and plant nutrients, so that new land had to be cleared for food production. Burning the land over in ways that allowed reforestation was viable in regions that were still only sparsely populated. In this era farming and animal husbandry were still separated.

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Once we sink a hoe, spade or plough into the soil, we begin to change the soil itself



The ability of cattle to digest fodder became the basis of food security

A great deal of land in this world has been ruined through over-exploitation after clearing and burning over woodland. Wind and water have carried off the last remaining nutrients and organic material.

**“Farmland is the child of the meadow”**

Animals can get by on things we humans cannot eat. Grasses and even the leaves of shrubs and trees were prerequisites to the colonization and cultivation of northerly regions. The climate in the North underwent a drastic change in the period between 1800 B.C. and 500 A.D. Winters grew longer and colder so that farmers needed more winter feed for their herds. Farmsteads expanded with new structures to house both animals and stores. Survival itself during the half of the year when the earth lay barren required much more work in the few summer months. Plants had to be harvested to supply food and feed for man and beast to last the entire year.

The ability of cattle to digest fodder became the basis of food security. Much of the food put by for the winter was produced by animals: their milk and their meat. In the winter months manure accumulated in barns and barnyards; when Spring came, it was spread over the small fields around the villages that were used to grow grain. Thus bread, too, was based on the animal husbandry .

Beyond the cultivated fields lay meadows that provided winter feed and, via the animals, manure that fertilized the land. This is the background to the old Swedish saying, “Farmland is the child of the meadow”. The interplay of cropland and meadow was the key to sustainability. The land that provided hay was in most cases many times greater than the land under cultivation. Beyond the meadows, sometimes far from the village, lay summer pasturage (often wooded in the North), where animals were herded.

**Legumes in the meadow and fallen leaves fertilized the soil**

The meadows were supplied with nitrogen from wild legumes such as clovers, vetch, vetchling or meadow-pea (*Lathyrus pratensis*), and bird’s foot trifoil (*Lotus corniculatus*). Weathering of the soil provided potassium, phosphorus and all the other tracer elements of importance to life, and here deciduous trees played an important role by virtue of their deeper and wider root systems. Trees absorbed nutrients and transported them to the leaves in their crowns; these vital minerals were returned to the topsoil when the leaves fell in the autumn.

This kind of agriculture seems to have worked well for centuries,

despite the fact that nutrients were continuously removed from the meadows that provided feed for the live stock. Nutritious grasses and herbs were cut and removed from the meadow; when the hay was digested by animals, the nutrient content was eliminated in the form of manure and urine, which later fertilized the other, more cultivated fields used to grow grain and turnips. This flow, from the meadow, via animals, to cultivated land was viable as long as the tilled area was small in relation to the meadowland (Figure 15).

Combined hay-making and keeping animals was a step toward sustainability from the harsher slash-and-burn farming that preceded it. A relationship was established between the cattle management and the growing of crops, although grazing and cultivation were still physically separate – a humanly organized interaction between soil, cultivation and animals.

Meadow agriculture appears to have been productive enough to support the population of its time, and as long as new land could be cleared and cultivated.

Slash-and-burn techniques continued alongside hay-making, either on small, temporary clearings in the forest or in connection with clearing new land. In Savolax, in eastern Finland, piles of stones show that land was burned and cleared as late as the early twentieth century.

As the population grew, so did the degree of grazing and growing of winter hay for the animals. Intensive cutting of meadow grass without being able to return fertilizer to them leads to gradual depletion of the meadows' fertility, and declines in the amount of hay limit the size of herds. Thus, population growth and the need to feed more people led to successive degradation of the land. Manure was in such short supply that there was not enough for all the land under cultivation, let alone the meadows. The numbers of animals, and thus the amount of manure produced, was limited by the gradually declining amount of hay. In time, clearing of forested land for agriculture was also limited by competing interests: harvesting timber and wood fuel. Charcoal was also vital to the Swedish iron and early steel industries.

A medieval pattern of land ownership, with small and scattered holdings around villages, made it difficult to introduce more rational farming methods in Sweden toward the end of the eighteenth century, when the total cultivated acreage in the country was about 800 thousand hectares, and hay-producing meadows covered an additional two million hectares.



Thus, population growth and the need to feed more people led to successive degradation of the land



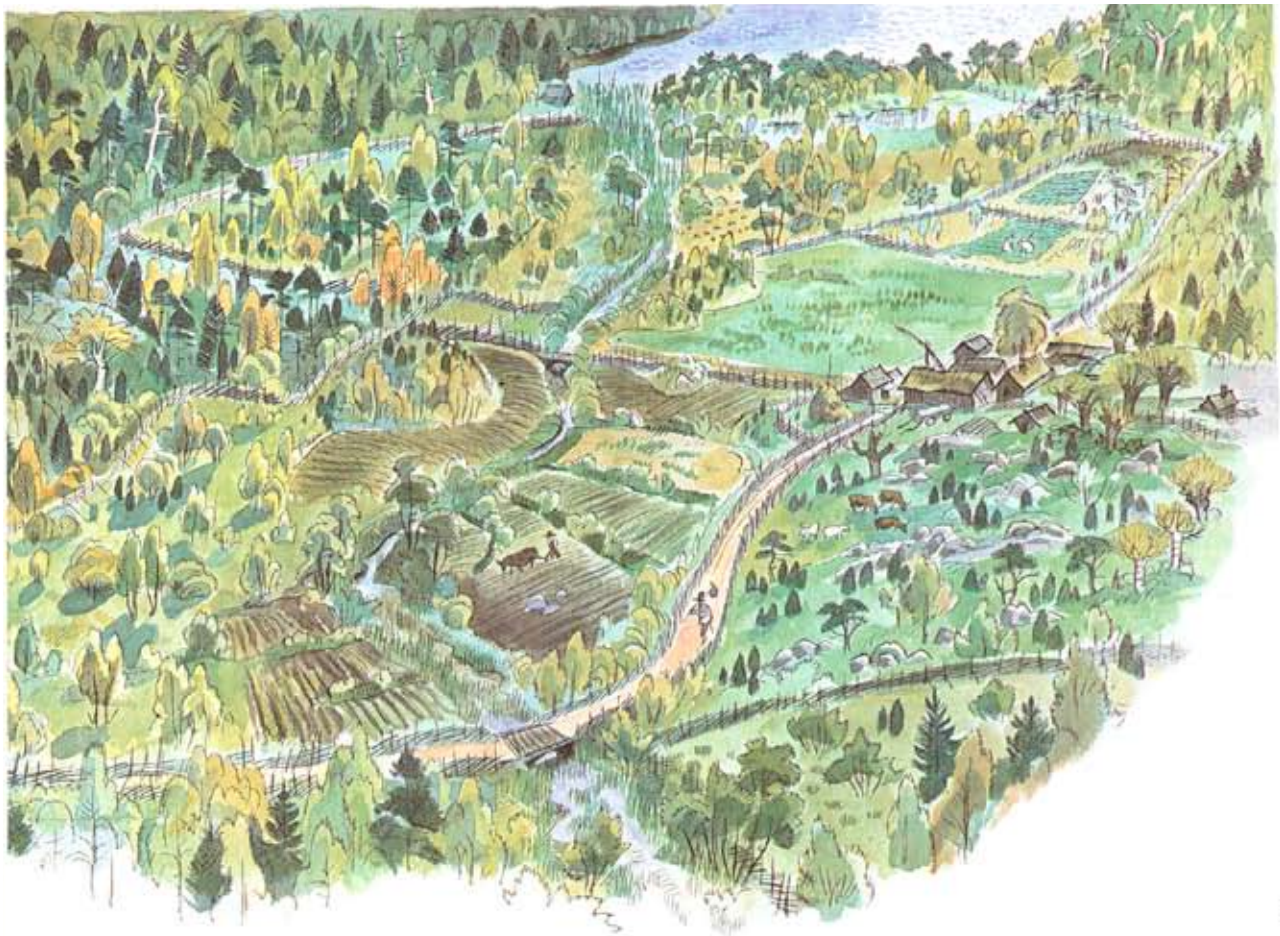
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Figure 15 Documentary illustrations by Gunnar Brusewitz from an area of Roslagen, north of Stockholm, show how farming in that area developed. (See also Figures 17 and 18.) Permanent residence in villages was introduced in the late Bronze Age (about 800 B.C.) when the climate cooled. It was possible to establish villages thanks to

herding and use of natural lands for cultivation, grazing and harvesting grass and leafy branches for winter fodder. Only a small part of the land was put under the plough and fertilized with the manure that accumulated during the winter. The size of the harvests of grass and leaves from meadowland, plus harvested marsh grasses, set the limit for the amount of hay available to the animals, and the size of flocks and herds determined the

amount of fertilizer that was available. Together, these factors limited the ability of the land to support villagers, whose numbers continued to grow. Source: Brusewitz, G & Emmelin, L (1985) *Det föränderliga landskapet: utveckling och framtidsbilder* [The changing landscape: past and future], Stockholm: LT.

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© Gunnar Brusewitz/BUS 2012

### Legumes put an end to famine

Meadow agriculture was followed by farming using crop rotation. Between 1800 and 1950, the population of Sweden grew from 2.3 million, despite considerable emigration. This represents a population growth of 200 per cent in the span of 150 years (Figure 13). In Finland the population grew from one million in 1800 to five million in 1950. Similar rates of population growth are noted even today, but in other parts of the world. The food crisis in those countries can be solved in the same way as it was solved here in the North, long before chemical pesticides and synthetic fertilizer were in use.

As recently as the late 1700s people still starved to death in Sweden when crops failed. In Finland even much later. It was the introduction of crop rotation, with periods of legume-rich fallow that made famine a thing of the past, despite substantial population pexporter of agricultural products in the early 1900s. It was thanks to crop rotation with legumes and a balanced circulation of nutrients between plant crops and animal husbandry that Sweden could make the transition from widespread hunger to food security, despite a growing population. It is important that the knowledge that made this possible, without either chemical pesticides or synthetic fertilizer, be made available to those in need of it today, that it becomes part of the training they receive so that they may more confidently face a future in which strategic resources are in increasingly short supply.

### Clover feeds animals and soil alike

A hectare planted with clover can fix up to 200 kg of nitrogen and yield harvests that are triple or quadruple the yield a natural, uncultivated meadow of the same area could produce (Figures 17 and 18). Ley plantings with lucerne can fix 300 kg of nitrogen per hectare, given suitable soil and sufficient precipitation. Among agricultural plants, legumes have a unique ability, together with the bacteria that live in symbiosis with them, to fix large amounts of atmospheric nitrogen. Furthermore, legumes like clover and lucerne have deep root systems that permit symbiosis with fungi in the soil, so-called mykorrhiza, that help to free minerals in the soil through weathering, and leave extensive nutrient-rich root systems in the soil after they have been harvested for the benefit of the crops that follow in the rotation. What is more, they build up the fertility of the soil. This is the key to the agrarian revolution that soon followed. Cropland with diverse crop rotations that included legumes in the clover-grass land ley soon replaced the traditional meadow (Figure 19).

The importance of legumes for productivity was known to the Chinese already 7 000 years ago, and it was known to agriculturalists in the Roman Empire. The poet Virgil, who lived in the time of

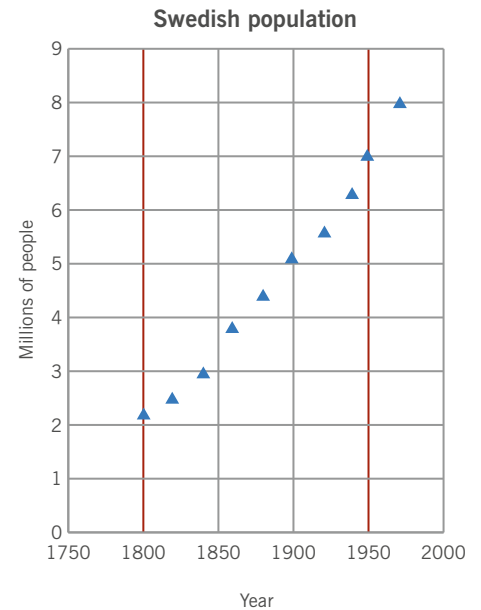


Figure 16. The population of Sweden increased from two million to seven million between 1800 and 1950, before farmers had begun using synthetic fertilizers and chemical pesticides on any larger scale.





Figure 17. Fallow, first year: a mixture of red clover and grass alongside an experimental plot with grass only on the Skilleby Experimental Farm in Järna. A mixture of clover and grass produces a harvest at least triple that produced by grass alone. This provides a measure of the soil-borne nitrogen with no nitrogen-fixation, and thus a measure of the additional nitrogen fixation. Photo: Artur Granstedt

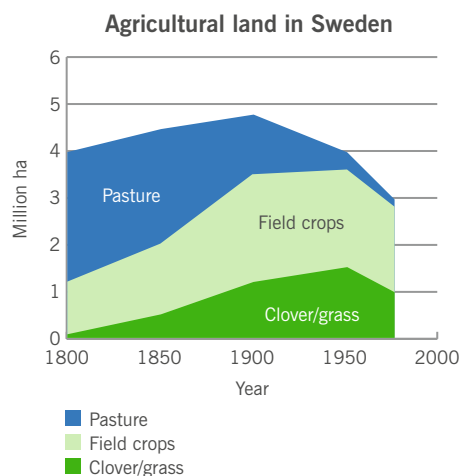


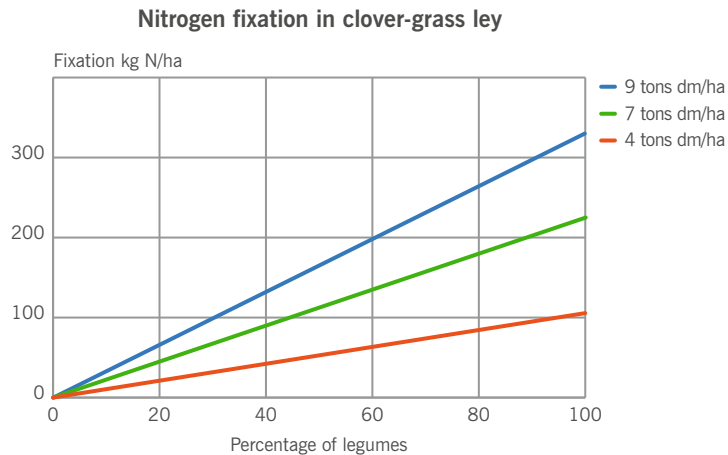
Figure 19. Agricultural production could be multiplied many times over thanks to the fact that land planted with nitrogen-fixing plants (clover and, on some soils, lucerne) expanded at the expense of natural meadow grasses.

Caesar Augustus, praises the virtues of legumes, but this knowledge seems largely to have been forgotten here in Europe sometime in the Middle Ages. Cultivation of clover and lucerne became more common in Europe in the seventeenth and eighteenth centuries. When first introduced into the Nordic region, clover seed was an import commodity; the ability to grow, sort and clean seed was a major step in the development of agriculture in these parts. Linnaeus spoke of the value of sweeping up and sowing meadow seed that accumulated on the floors of storage sheds, but the specific sorting of clover seed was the start of what was once referred to as the “cultivated meadow”.

Crops having different requirements regarding nutrients, different root depths, and different characteristics with regard to weeds, pests and diseases followed one another in patterns of crop rotation. The several years of ley were regenerative, whereas other crops in the rotation broke down humus and took nutrients out of the soil. This balance between regenerative and extractive species was crucial. Root crops became increasingly important since they gave good yields, had high nutritional value and were a row-crop, which permitted systematic weeding. Potatoes, which were known in Europe botanically as early as the 1500s, began to be grown as a food crop in the 1700s. Their importance as a staple crop in the 1800s is often emphasized, but the fact is, potatoes would not have been able to be grown without the availability of plenty of manure, which in turn was possible only thanks to the expansion of animal husbandry, based on access to more hay – all of which ultimately depended on the fixation of atmospheric nitrogen by legumes. You have to consider all the interlocking parts.

Growing grass together with clover or lucerne provides nitrogen to the crops that follow in three ways. When the grass has been cut, harvest remains and roots are left in and on the soil. This organic biomass accumulates for several years until the ley period ends and the plot is ploughed. Some deterioration of the plants takes place even during the ley period (generally 2-3 years), but most takes place after it. Decaying plant material releases some of the nutrients stored in stubble and roots by the process known as mineralization, and the amount of nitrogen – especially nitrogen – that is released depends on the amount of decaying biomass and the ratio of carbon to nitrogen. The remainder of the harvest residues goes to form humus and is of decisive importance to the maintenance and creation of mull in the soil. Several years of studies of this process were conducted in a project involving farms in Sweden and Finland, which I led.\* The third way in which leguminous ley contributes to the

\* Granstedt, A & Baeckström, G (2000) Studies of the preceding crop effect of ley in ecological agriculture. *American Journal of Alternative Agriculture* 15:2:68-78.



supply of nutrients to following crops is via flocks and herds. Most of the nutrients in the hay is metabolized in the animals' digestive systems and is eliminated. The animals' manure and urine can be distributed to different crops in the rotation according to their needs. All this is explained in detail in textbooks on organic farming.\*\*

### The dispersion of farmsteads, an agrarian revolution

Initially, only the larger estates in continental Europe – in, for example, Poland – had the technical knowledge and resources to make the necessary changes. A well-known pioneer in Sweden was Rutger MacLean on the Svaneholm estate in Skåne. Despite strong protests MacLean had the villages on his land torn down and the farms redistributed so that each tenant farmer had a house, barn, sheds, etc., and was surrounded by contiguous land for which he was personally responsible. New techniques – including crop rotation and cultivation of legumes – were introduced at about the time royal edict forced even autonomous farmers to leave their villages and relocate out in the countryside. In Sweden, this radical land reform was carried out between 1803 and 1827. It was followed by similar reforms in ensuing years. As shown in Gunnar Brusewitz' illustrations Figures 15, 20 and 21 of a confined area in Roslagen, northeast of Stockholm, farms acquired larger contiguous fields, and meadows were successively put under the plough. The pictures also show how farmhouses are surrounded by fields of legumes (green) and grain crops (yellow), which changed place according to a given rotation. Farmers were no longer subject to decisions of the village council, but were instead on their own. In Sweden, the 'revolution' started in the south and gradually moved northward.

\*\* Granstedt, A (ed.) (1998) *Ekologiskt Lantbruk: Fördjupning* [Organic agriculture: in depth]. LT Förlag; Bachinger, K S & A Granstedt (eds.) (in press) *Guide Book in Conversion to Ecological Recycling Agriculture*.

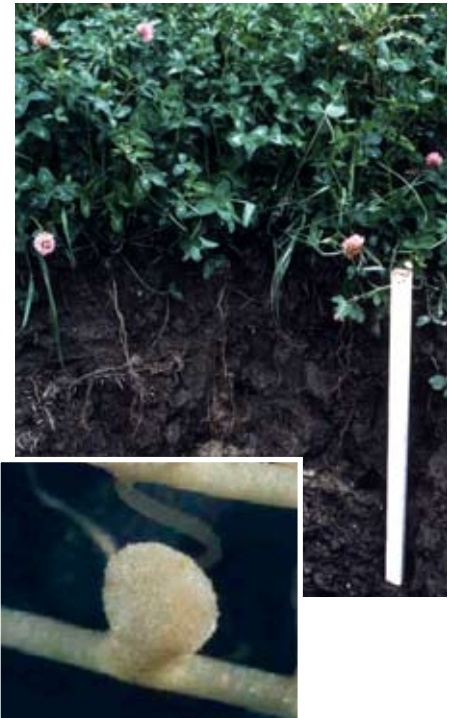


Figure 18. Ley, first year: a mixture of red clover and grass on the Skilleby Experimental Farm in Järna. The cross-section exposed in the image to the left shows root development in the topsoil (0-20 cm) and into the subsoil. The magnified image to the right shows the small nodules that contain nitrogen-fixing bacteria. The symbiotic relationship is this: the plant provides energy in return for reactive nitrogen, which the plant can absorb. The energy source is sunlight, absorbed by nitrogen-rich chlorophyll in the plant's leaves. Through photosynthesis the plant forms energy-rich carbohydrates that its bacteria use to fuel the nitrogen-fixing process. Here we have a classic example of the interdependent processes that make life possible.



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Figure 20. Above we see that three farms have replaced the village that existed before the great land reform. Each farm practices crop rotation in which symbiotically nitrogen-fixing legumes play an important part, and each has herds and other animals in proportion to the amount of feed the farm produces. The animals' manure and urine returned to the soil direct during the summertime and during the wintertime collected on the dung place closed to the cow barn and then brought back the field and soils in the crop rotation. Brucewitz 1985.

Source Brucewitz G & Emelin. L. 1985. *Det föränderliga odlingslandskapet, utveckling och framtidsbilder. [The changing landscape: past and future]*, Stockholm: LT.

Denmark retained more of the original village structure, as is common in the rest of Europe. But even in Denmark fields were amalgamated into larger parcels (as in Figure 20). Danish farmers cultivated clover to an increasing extent as early as in the 1700s, which contributed greatly to the transformation of poor rural landscapes and depleted soils. The transformation is well-documented in a doctoral dissertation by T. Kjaerrgaard from 1994.<sup>21</sup> Cultivated meadows with clover and lucerne were developed even earlier in southern Europe. The history of the adoption of legumes and crop rotation and its importance in Sweden was documented by Hugo Oswald, rector of the former Ultuna Agricultural Institute in 1962<sup>22</sup>.

The agrarian revolution that started in the nineteenth and continued into the twentieth century was a function of impressive advances in

<sup>21</sup> Kjaerrgaard, T (1994) *The Danish Revolution 1500-1800*:

<sup>22</sup> An ecohistorical interpretation. Cambridge University Press. Oswald, H (1962)

*Vallodling och växtföljder: Uppkomst och utveckling i Sverige [Cultivated meadows and crop rotation: Introduction and development in Sweden]*. Stockholm: Natur & Kultur.



several technologies. Better implements and stronger horses allowed the cultivation of land – heavy clay, for example – that previously could not be ploughed. Covered drainage was of great importance in rationalizing operations and improving the soil's productivity. Lakes were regulated and marshes drained, making it possible to bring new, humus-rich land into production. Adding sand and clay to nutrient-poor humus soil improved the overall status of croplands. So did the practice of spreading marl (calcium-rich soil) over fields. Potassium and phosphate fertilizers began to be applied more widely; they increased the productivity of marshland in the early years of the twentieth century. Cultivation of marshes was, however, a short-lived phenomenon, a response to the destruction of organic biomass through mineralisation. Animal breeding, dairy production, and construction work contributed to rural development and expanded opportunities for non-agricultural employment.

Animal husbandry practices were improved through instrumental breeding, which resulted in more meat and milk, made possible by the availability of more hay, which in turn was possible thanks to the sowing of legumes. The development of the dairy industry, slaughterhouses, and rational grain management and milling on larger farms and by private companies, plus the organization of producers' cooperatives were other phenomena that contributed to employment and the standard of living.

#### **How knowledge spread**

All these developments were accompanied by an impressive diffusion of knowledge – first, to the noble estates; then, in the nineteenth century, to manor estates; and, in the twentieth century, to smallholding farmers. In 1813, Crown Prince Carl Johan, later King Karl XIII, founded the Royal Swedish Academy of Agriculture, the purpose of which was “to identify [and develop] the foundations of national self-sufficiency in the natural potentialities of the land”. The Academy developed new agricultural methods through extensive experiments on farmland outside Stockholm. A profitable model farm was established there, and new tools, varieties of crops, methods of cultivation, breeds of animals and animal husbandry techniques were tested empirically. The findings of these experiments were spread throughout the country by a network of local Agricultural Societies by means of extension training, demonstration plots and farms, and publications. As the prime forum for this new branch of science, the Academy awarded prizes each year to farmers who distinguished themselves in terms of productivity and technical prowess.

By the early twentieth century, nearly all uncultivated meadowland had been supplanted by cultivated pasturage and hayfields. Hardly anyone mowed natural meadows any longer. The meadows that did exist



The agrarian revolution that started in the nineteenth and continued into the twentieth century was a function of impressive advances in several technologies

had more the character of supplementary pastures, where calves and young animals could graze in the summer months.

### Recycling on each farm

A prerequisite for this kind of farming is that every farm had just as many animals as it could feed. The greater part of what was, and continues to be, grown was animal feed. The difference between then and now is that then, all manure, with all its important nutrients, was returned to the land in an unbroken cycle. At mid-century, cultivated grassland with legumes covered roughly 40 per cent of all cultivated land in Sweden. The proportion was about the same in other Nordic countries, as well.

A diversified crop rotation consisting of restorative clover pastures, feed crops, grains and root crops, combined with animal husbandry, made it possible to achieve a high level of productivity, given the varieties and techniques of the time. In addition to feeding a national population of seven million people Swedish farm production also fed 500 000 horses, still the principal draught 'engines' in Swedish agriculture of the 1950s.

Until the 1950s, Swedish farms purchased relatively little in the way of fuels and fertilizer. Up to then, some minerals, potassium and phosphorus, were added to some soils, whereas nitrogen was chiefly supplied by legumes. *At mid-century Swedish agriculture reached a peak: neither before nor since have Swedish farms had such productivity, based on their own, renewable resources.* Farms and, later, local producer cooperatives were still responsible for a substantial share of the processing of food products, based on local resources. Roughly one-fourth of the national population were employed in agriculture as late as 1950.

In Sweden, Edward Nonnen pioneered cultivating clover in farming practices. At first, Nonnen was scoffed at when he sowed clover on his initially run-down farm at Degeberga in Västergötland. But the farm soon gained recognition as a model for others. Sweden's first agricultural institute, which offered two levels of education, was founded here. Later, training was taken over by the Ultuna agricultural institute outside Uppsala. Still later, the Ultuna institute became Sweden's first Agricultural University,

A famous proselytizer in Sweden, Per Jönsson Rösjö wrote and published numerous books on agricultural practices and lectured all over the country, sometimes in the local church when no other facilities were available. Rösjö's motto was "Book and Plough". His school for smallholders was founded with funds raised among farmers nationwide. Ultimately, the school was awarded a government grant, paid annually, which covered the costs of demonstration crops for educational purposes.

In Finland, Nobel laureate Artturi Virtanen pioneered research on how, with the help of legumes, farms might become self-sufficient in nitrogen.



At mid-century Swedish agriculture reached a peak: neither before nor since have Swedish farms had such productivity, based on their own, renewable resources

He demonstrated his findings on his own property outside Helsinki, which he purchased in the 1930s. Only a few years later, however, synthetic nitrogen fertilizers took over in Finland, too.

### **Broken cycles agriculture**

In the first half of the twentieth century, farms both raised crops and kept livestock in numbers that the farm could support. After 1950, increased use of nitrogen fertilizers, above all, broke this vital link between cattle, cultivated meadows and grain production. In the beginning, synthetic NPK fertilizer was only used as a supplement, but as farms began doing away with their dairy herds to concentrate on field crops, synthetic fertilizer began to replace manure. Farming without animals and cultivated pasture became increasingly common, while herds and flocks were concentrated on specialized and more intensive farms. The sum of these developments was structural reorganization with two main trends, each leading to extreme specialization, which would have far-reaching negative consequences. On the one hand, farms specialized in grain production, which, in the absence of cultivated ley and cattles, was dependent on chemical fertilizer Figure 21. Other farms specialized in dairy and meat production.

Even though 80 per cent of all crops are feed crops, most Swedish farms have no livestock; animals are instead kept in specialized animal farms. Today, Sweden has about 50 000 commercially managed farming enterprises. Sixty per cent of these are totally specialized in raising crops, and 30 per cent are specialized in breeding or dairy and meat production that is based to a large extent on locally purchased and/or imported fodder. Only 10 per cent still combine animal and crop production for the market. Total consumption of dairy products and meat is on the increase, whereas these products are produced on ever fewer farms, with ever greater numbers of animals. When the size of the herd exceeds the amount of feed the farm can produce, the gap has to be filled with feed that is purchased. The result is a growing surplus of nutrients from the animals in the form of manure. The manure produced on these farms and distributed on the fields each year contain more nitrogen and phosphorus than the crops on the farm can utilize; ultimately, the surplus is wasted on the surrounding natural environment.



Two main trends, each leading to extreme specialization

<sup>23</sup> Granstedt, A (1995) Studies on the flow supply and losses of nitrogen and other plant nutrients in conventional and ecological agricultural systems in Sweden. *Biological Agriculture and Horticulture* 11:51-67.

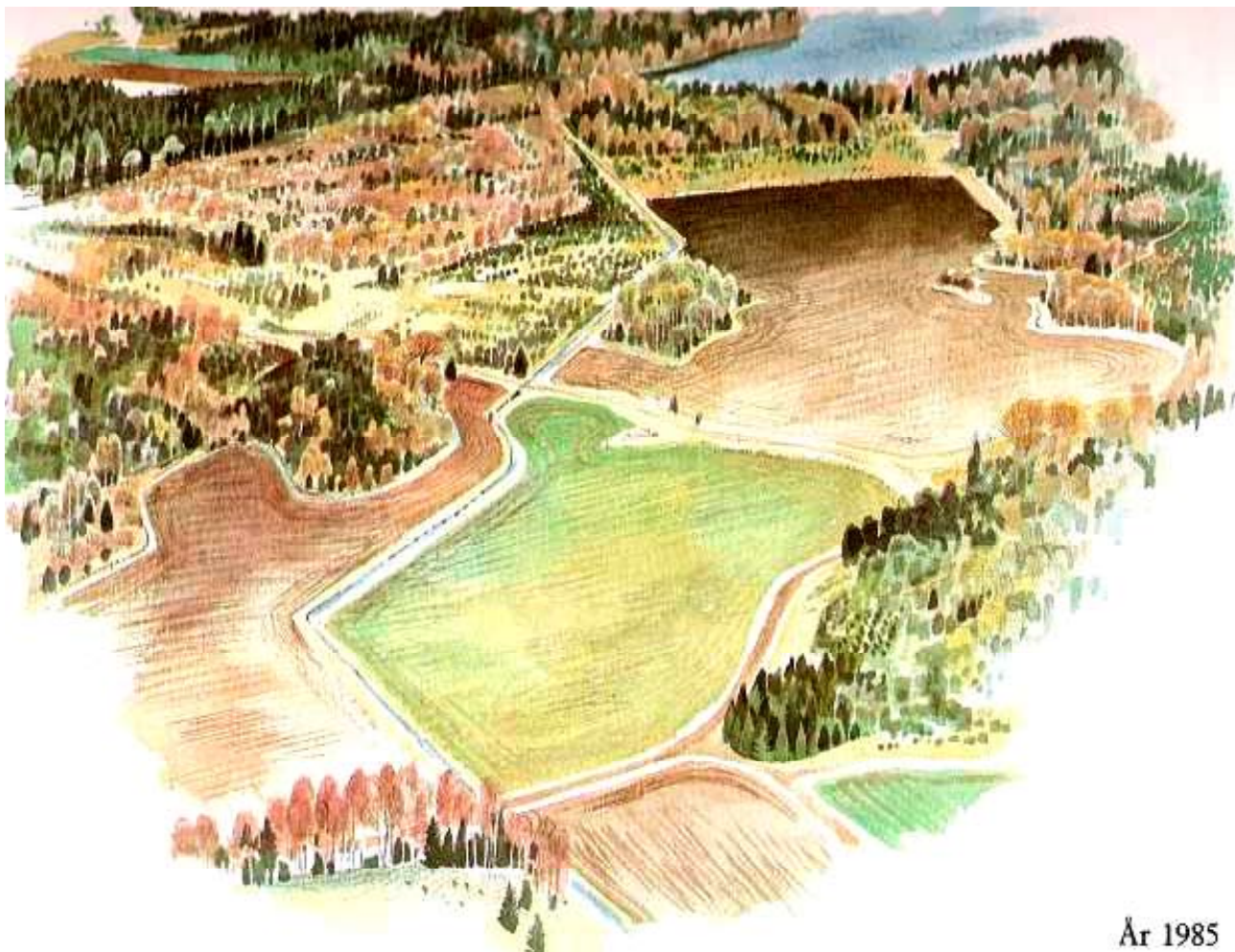
## Farming in the Baltic sea region

Figure 21. The illustration shows the same land as in Figures 15 and 20, but quite transformed since 1900. Farms, fenced pasture, grassland, clover fields and animals have disappeared. Now the land is used for grain production exclusively. The fields pictured are now part of a larger farm. Structural ra-

tionalization in the postwar period has had thoroughgoing consequences; many farms have been amalgamated into larger ones. The production and use of synthetic fertilizers using fossil energy has made it possible to do away with both flocks and herds, whose manure was once so vital nutrient recycling, and

reliance on legumes as a source of nitrogen. An exclusive focus on grain production led to growing problems with weeds, crop damage and diseases, which in turn led to greater use of pesticides. The trend continues to this day within the whole Baltic Sea drainag area. Brusewitz 1985.

Source Brusewitz G & Emelin. L. 1985. *Det föränderliga odlingslandskapet, utveckling och framtidsbilder.*[The changing landscape: past and future], Stockholm: LT.



© Gunnar Brusewitz/BUS 2012

År 1985

The cyclical recirculation of organic material and nutrients has declined within individual Swedish farms, while the amounts of both nutrients applied and nutrients lost have increased<sup>23</sup>.

### Increasing waste

The use of synthetic fertilizers increased dramatically in the Nordic region in the interval 1950-1980 (Figure 22). Use of chemical fertilizers peaked in 1980 in Sweden, whereas in Finland the peak came ten years later. The increase in nutrients applied to the soil has not been accompanied by any increase in the removal of nutrients in the form of food products. Instead, the gap between the amounts applied and the amounts removed has steadily widened. Additional nitrogen is added to our agriculture through imported feed, fallout of atmospheric nitrogen over the land, and biological fixation of the same. In 1980 farmers applied four times as much nitrogen and phosphorus, and eight times more potassium than was returned in the food, animal and vegetable, that the farms produced.<sup>24</sup> Since 1980, the average amount of potassium and phosphorus has declined, but the use of nitrogen remains at the same high level. Although the surfeit of phosphorus is less today on average, losses (waste) are still high. Phosphorus continues to accumulate at animal farms, despite the fact that less excess phosphorus is applied to grain crops than previously. The situation is similar in Finland, where farmers apply even more synthetic phosphorus fertilizers than in Sweden. Denmark imports considerably more fertilizers in the form of feed and feed supplements than any other country around the Baltic Sea.

The gap between the volume of fertilizers applied and the volume of food produced represents a loss from the agroeconomic system, which in the case of nitrogen and phosphorus results in harmful environmental pollution (Figure 22).

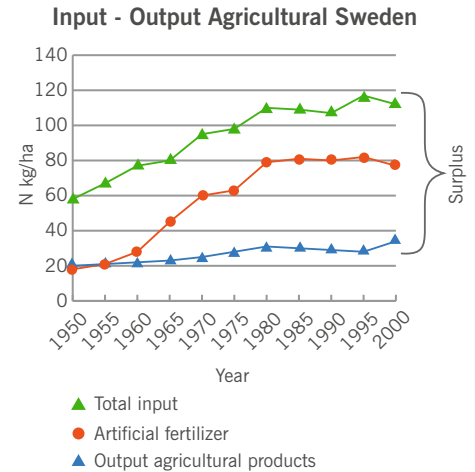


Figure 22. Between 1950 and 1980, annual use of synthetic nitrogen fertilizers in Swedish agriculture increased from under 20 kg/ha (20 kg N/ha) to 80 kg/ha (80 kg N/ha), and it remains at this high level in conventional agriculture today. The difference between the total nitrogen applied (110 kg N/ha, consisting of synthetic fertilizer, imported feed, biological fixation and fallout of atmospheric nitrogen, and the removal of nitrogen in the form of food products (30 kg N/ha in the form of animal and vegetable products) afflicts the surrounding natural environment through emissions (ammonium and 'laughing gas') to the atmosphere and effluents of nitrogenous compounds to lakes, streams and the sea (a principal cause of eutrophication of the Baltic Sea).

<sup>24</sup> Granstedt, A (2000) Increasing the efficiency of plant nutrient recycling within the agricultural system as a way of reducing the load to the environment: Experience from Sweden and Finland. *Agriculture, Ecosystems & Environment* 1570:1-17.





Photo taken in the Stendörren Nature Preserve (Södermanland). Photo: Helle Reeder

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Figure 23. Nitrogen and phosphorus compounds are transported to the sea via runoff and streams. There, they stimulate the growth of algae, leading to so-called algal bloom. Algae are marine organisms (Thallophyta) that use photosynthesis to fuel their growth, provided that the proper conditions for growth are available. Access to nitrogen and phosphorus are vital to their growth.

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The losses of nutrients from agriculture are a prime contributor to the eutrophication of streams, lakes and, ultimately, the sea (Figures 23 and 24). When colonies of algae, which consist of microscopic plankton, die in the autumn, the decomposition process consumes oxygen. The resulting oxygen deficiency kills fish and leads to the expansion of lifeless areas across the seabed (Figure 25).

Other human activity that contributes to the leakage of nitrogen and phosphorus compounds to the sea takes place in households, various

aspects of 'urbanity', and sewage treatment facilities (Figures 26a and 26b). Forests leak nitrogen and phosphorus when large tracts are felled and wherever forests are fertilized. Industrial facilities leak nitrogen, and both factories and traffic give rise to nitrogenous fallout. Fish farms, too, contribute to eutrophication, unless they are confined in closed aquasystems. Eutrophication of the Baltic as a consequence of leakage of nitrogen and phosphorus is one of the most serious environmental problems that the countries of the region have faced these past couple of decades. Nor have efforts to date achieved any notable improvement (Figures 27).

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*Figure 24. Satellite image of algae in bloom in the Baltic Sea, Summer 2006. Source: NASA (image processed and made available by SMHI).*

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<http://www.smhi.se/kunskapsbanken/oceanografi/algblomningar-i-ostersjon-1.3008>

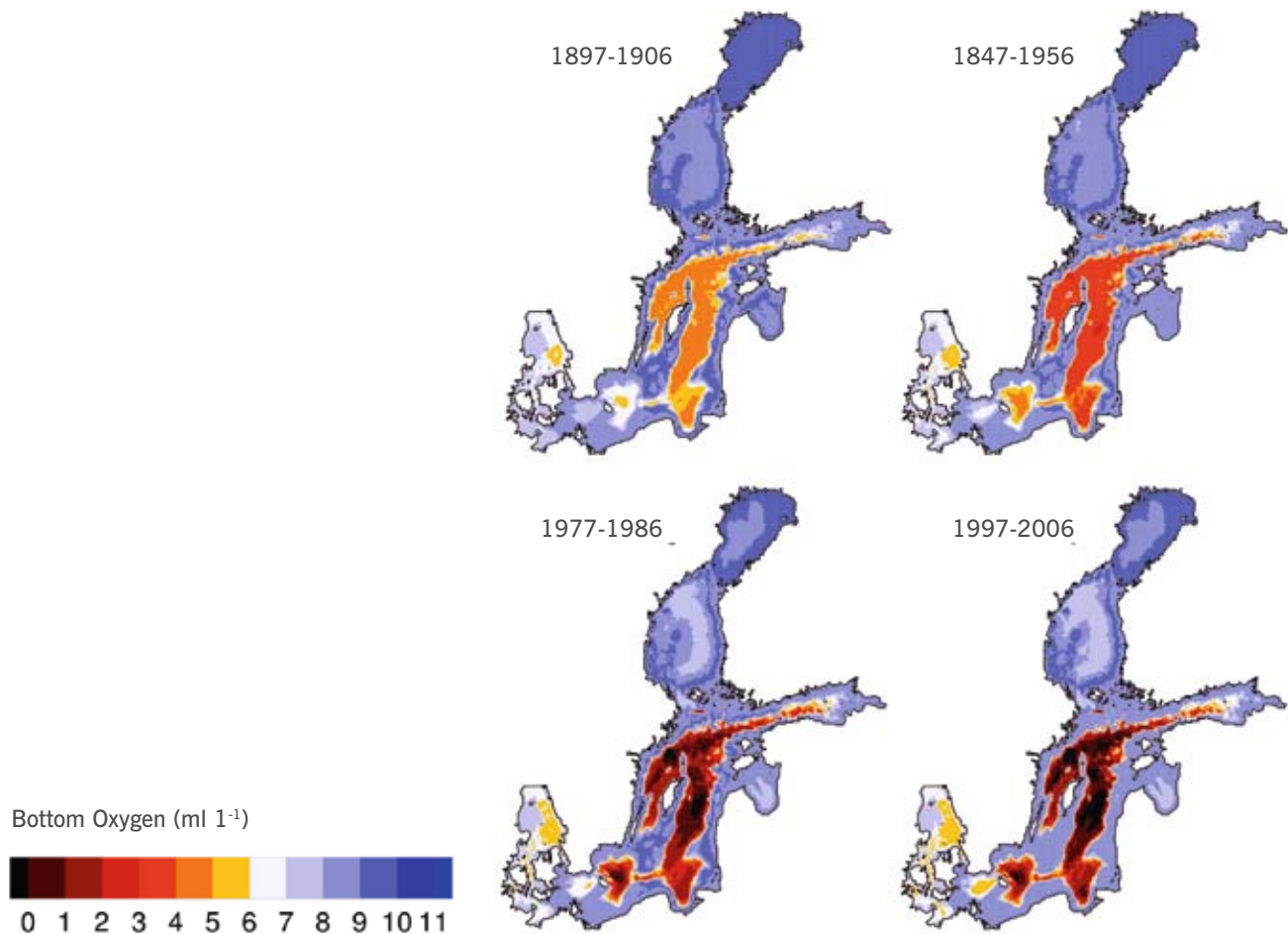


Figure 25. Areas of the Baltic Sea that have oxygen-free ( $< 2 \text{ ml O/liter water}$ ) seabeds (Gustafsson et al 2012<sup>31</sup>).

In strictly economic terms, eutrophication has hurt both the fishing industry and tourism. In addition, we have the problem of nitrates in drinking water in areas of intensive agriculture. A surfeit of nitrogen in the soil also contributes to emissions of nitrous oxide (a.k.a. 'laughing gas'). Nitrogen pollution of the environment is today a global problem, with respect to both pollution of the seas and climate change.

Thanks to the valuable work with nutrient balance calculations and adviser service program within "Greppa näringen" (catch the nutrients) the utilization of the nutrient surplus in manure is more effective today. The earlier overuse of phosphorus fertilizer has been stopped in conventional crop production, although there is still a surplus of phosphorus on animal farms due to the import of nutrients in the form of fodder. The surplus of nitrogen in conventional agriculture is still increasing depending on the ongoing concentration of animal production. The small reduction of nitrogen surpluses per ha in Sweden is a result of the increased acreage of ecological agriculture without use of artificial fertilizer.

<sup>31</sup> Gustafsson B.G., Schenk F., Blenckner T., Eilola K., Meier h.E.M., Müller-Karulis B., Neumann T., Ruoho-Airola T., Savchuk O.P., Zorita E., 2011: Reconstructing the development of Baltic Sea eutrophication 1850 – 2006, *Ambio*, submitted.

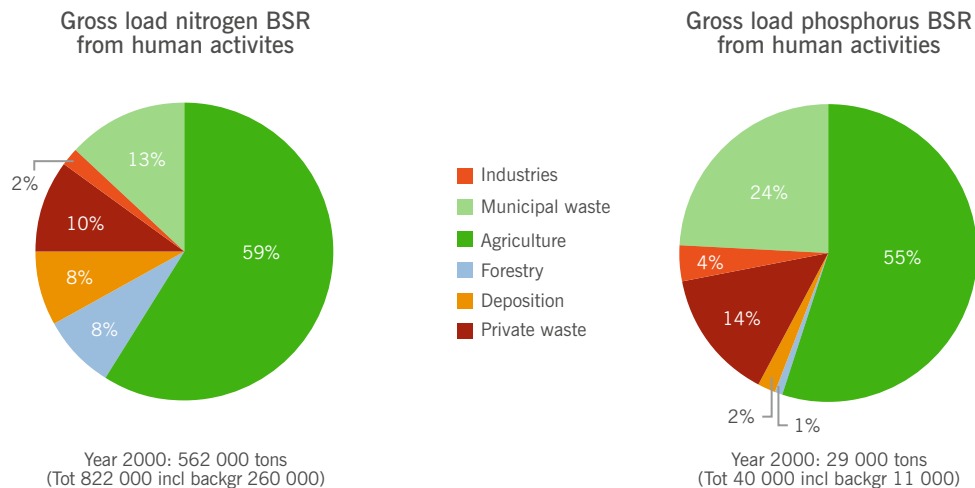
The total surplus of nitrogen within Sweden is lower today, but this is due to decreased agricultural production and increasing food imports, with the consequence that we also export part of our environmental impacts.

**Since 1950, two farms out of three have ceased to exist**

Farming in Sweden today bears only a slight resemblance to farming as it was practiced in the early 1950s. Above all, there are so few people about. The landscape, too, has changed. Employment in agriculture has fallen from fully a quarter of the work force to no more than 1.1 per cent. Further back in time the share was even greater: in 1870, 71 % of the population were employed in agriculture and agriculture-related occupations. Machinery to work the soil, to sow, harvest, thresh and other agriculture equipment have made this change possible; another factor is a comprehensive rationalization of the cultivated area. Agricultural holdings have been amalgamated. Two-thirds of the farms that existed in 1950 are gone today; most of them have been absorbed into surrounding farms. In the same period the acreage under cultivation has shrunk by nearly 1 million hectares.

The size of individual fields has increased as drainage ditches have been replaced by sunken culverts, and trees, piles of stones and outcroppings of rock have been removed. Even stone walls, products of

Figure 26 a and b. The gross load of nitrogen and phosphorus from different human activities in the Baltic Sea watershed. Source: Helcom (2005).





### Nitrogen and phosphorus load from the countries within Baltic Sea Drainage area

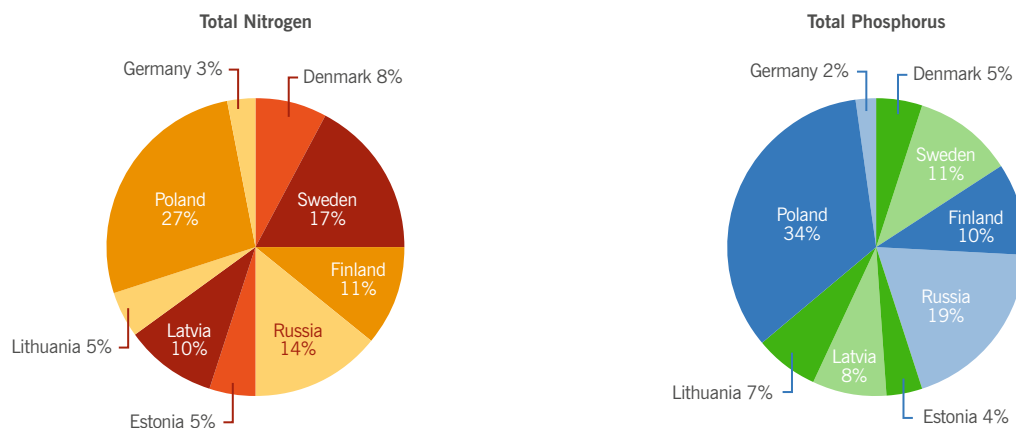


Figure 27. The total load of nitrogen and phosphorus within the Baltic Sea watershed and the shares of the respective countries, according to Helcom (2010).

Figure 28a. The flow of nitrogen from Swedish streams and rivers to the seas, 1996-2006 (tons/year). The variation between years is due to variations in precipitation and the volume of water carried to the sea. Despite year-to-year variations, the overall trend is upward. Source: Statistics Sweden 2007.

Figure 28b. The flow of phosphorus from Swedish streams and rivers to the seas, 1996-2006 (tons/year). Despite considerable upgrading of sewage treatment facilities and a decrease in the use of phosphorus fertilizer, there has not been any notable decline in marine pollution to date. Source: Statistics Sweden 2007.

back-breaking labor in yesteryear, were torn down. (The practice is now forbidden in law.) Small and impractically shaped fields have been abandoned and planted with forest. One person alone can now manage 100 hectares of land. Still, this is not the real problem. We cannot turn back the clock. Even farms in ecological balance may be managed using modern equipment that has replaced manual labor. Also, there is nothing that prevents taking measures to compensate for loss of biodiversity in more economically rational forms.

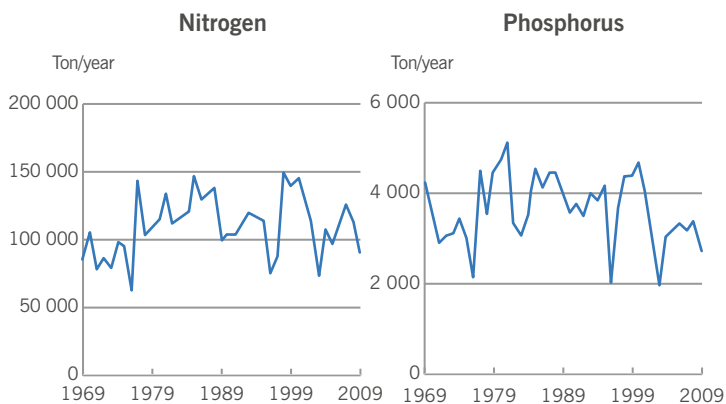


Figure 28a

Figure 28b

## BRIGHT GREEN, WEED-FREE FIELDS – THE CONSEQUENCES OF SPECIALIZATION

The resource-gorging agriculture we see today is a product of public policy, with new goals of efficiency and prescribed specialization, modeled on other branches of industry. Synthetic fertilizers were to allow grain production without animals. On farms that did have animals, their numbers grew. Herds now required increasing amounts of purchased feed and feed supplements. The ecological balance between soil, crops and animals had been broken.

The fundamental problems with agriculture today have their roots in the increased use of synthetic fertilizers and other chemical inputs in the 1950s, '60s and '70s in the Nordic countries. Chemicals made it possible for farms to specialize without paying heed to the laws of environmental ecology. Let us examine the history behind the bright green, weed-free fields that characterize rural landscapes today.

In the late 1940s the Swedish government formulated a set of objectives for the agricultural sector that sought to raise levels of efficiency, profitability and production volume. Government policy was set out in two major policy decisions – in 1947 and 1976 – that charted the course toward the agriculture we have today. The terms of reference given the commissions charged to outline policy options state explicitly that Swedish farms needed to specialize in order to become more efficient and to be able to reap economies of scale like other branches of industry. The means were at hand. Specialization could now be achieved by replacing recycling-based manure with synthetic chemical fertilizers. Exactly how corresponding coercive policy in the other Baltic Sea countries needs further study.

Farms that specialized in animals were fewer, but as the size of herds grew they became dependent on purchased feed from the specialized crop farms. To further enhance the productivity of dairy and meat production farmers began to import protein and energy-rich concentrated feed based on palm oil and soya. With that, the age-old interplay of the soil, crops and animals was broken.

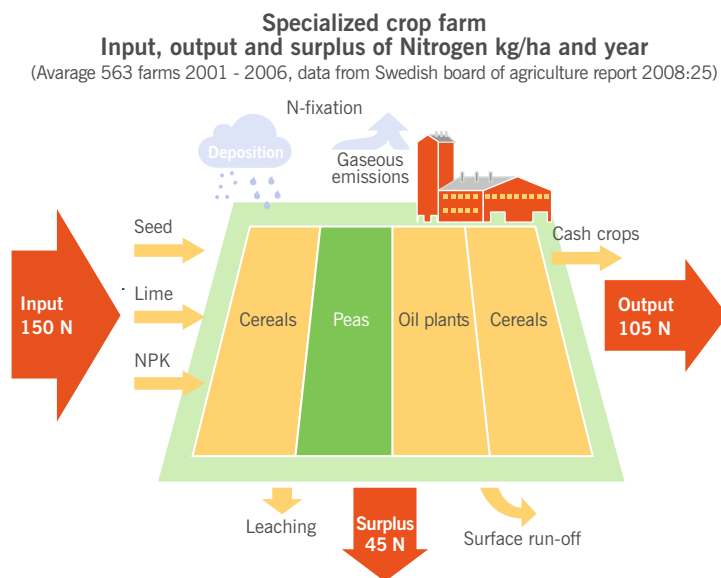
In Sweden, the instruments used to achieve these policy goals were price supervision, laws and regulations, and county Agricultural Boards, which had considerable influence over the acquisition of farmland and extension of credit. The Boards' advice and circulars were also important. Training at agricultural schools and courses offered by the Boards followed suit, so that students were trained either in intensive production of



With that, the age-old interplay of the soil, crops and animals was broken

pigs, poultry, or milk cows or they learned how to raise grain with the help of synthetic fertilizers and pesticides. It is reasonable to assume that the process was similar in Finland and Denmark. The process in Estonia, Latvia and Lithuania has a special history, where large agricultural collectives and state-owned farms were formed after the former landowners had been forcibly removed from the land and deported. The structure of land holdings in eastern and southern Poland, however, remained relatively small-scale.

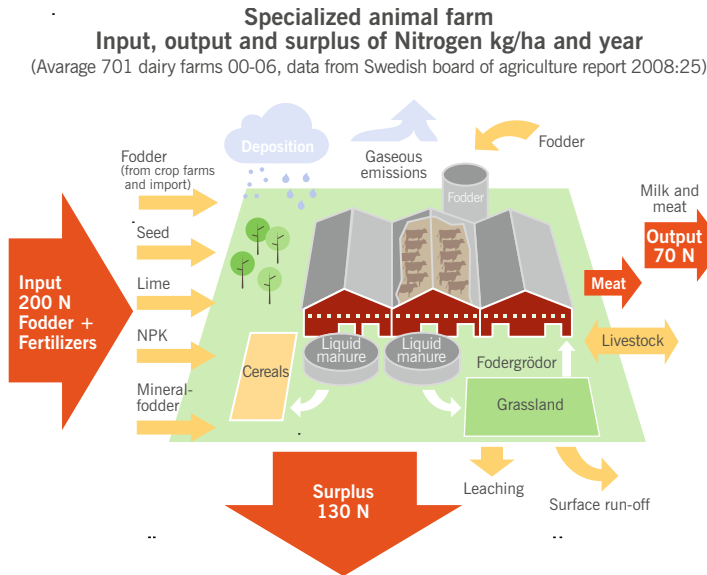
Figure 29. The nitrogen balance on an average specialized crop farm. The nitrogen brought to the farm is chiefly the nitrogen in synthetic fertilizers; smaller shares come through purchased feed and atmospheric N fallout. Of the total amount of nitrogen brought to the farm, 150 kg N per hectare and year, 105 kg is removed in the harvested grain, leaving a surplus of 45 kg that sooner or later will be lost to the air and water. About 80% of all grain production is feed crops that are sold to specialized animal farms.



### How the problem of nutrient losses arises

Calculating the balance of plant nutrients has become an important tool for analyzing the flows of nutrients so that we understand where and how nutrient losses occur. It is increasingly often used in Swedish agricultural extension work in the framework of a special program to monitor and reduce losses. Figure 29 gives a schematic picture of plant nutrient flows on an average Swedish grain-producing farm with no animals. Figure 30a describes the nutrient balance on a specialized animal farm. The greater part of nitrogen and phosphorus pollution comes from specialized animal farms, but some of the losses originate in the use of chemical fertilizers on specialized grain-growing farms, which sell their plant nutrients (in the form of feed) to the animal farms, where the major surpluses occur. In addition, there is the fact that the farms with the greatest plant nutrient losses are concentrated to certain regions – in Sweden as well as the other countries around the Baltic Sea.

Figure 32 shows the regional concentration of animals in southern



Sweden. Here the flows of plant nutrients aggregate, and the losses are greatest – a surplus of nutrients that runs, via surface and groundwater streams, out into the Baltic Sea. The distances between the two kinds of farms are depending on the regional specialisation mostly far too long to transport manure from animal farms back to the crop farms where the nutrients originate. (This is possible locally, provided the distances are short enough so that the transport costs are less than the value of the nutrients in the manure.) Nor are long transports of manure environmentally sound. A sustainable solution to the problem of nutrient surpluses and consequent pollution from agriculture requires a regional balance between crop- and animal-producing farms. The density of animals in the areas of greatest concentration needs to be cut by one-half. In order for the application of plant nutrients – and thus nutrient losses – to be reduced, the nutrients have to be recycled rather than accumulate, which results in the tremendous surpluses we find in overly animal-intensive farms and in whole regions of the country.

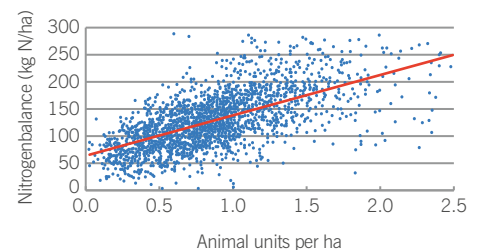
We find these phenomena with regional concentration of the animal production and consequently regionally gross surpluses and losses of nitrogen in all the countries around the Baltic Sea. Moreover, present European agriculture policy supports, even encourages, this regional concentration of animal production – and the problems associated with it.

### Nitrogen

Fully eighty per cent of the nitrogen applied to Swedish agriculture is lost to the surrounding environment. Some of the loss occurs in the form of ammonia and nitrous oxide (a.k. a laughing gas), some in the form of

Figure 30a. The nitrogen balance on an average specialized animal farm. The nitrogen brought to the farm is chiefly the nitrogen content of feed and feed supplements from grain-growing farms, but imports of feed and supplements, as well. Soy protein from Brazil in particular, which thus contributes to the Swedish nitrogen imbalance and leakage of nitrogen to the environment. Other sources of nitrogen are fixation of atmospheric nitrogen by legumes on farms that raise clover and synthetic fertilizers to specialized animal farms that produce milk and beef. Of a total 200 kg N per hectare and year, 70 kg is removed in milk and beef, leaving a surplus of 130 kg that sooner or later will be lost to the air and water.

**Nitrogen surplus as a function of the animal density**



30b. The relationship between nitrogen surpluses and the number of animal units on roughly 1 900 animal farms. The density of animals correlates directly with the size of the surplus (N/ha). High densities require larger amounts of purchased fodder, which increases the amount of nitrogen that is distributed over cropland as manure. Excess nitrogen leaks into the environment instead of being recycled. The variation noted between farms reflects differences in the efficiency with which farmers use manure. Sources: "Focus on Nutrients" (a multi-stakeholder program to reform fertilizer use in Sweden). Animal unit = one dairy cow, 6 calves or 3 yearlings.

\*An 'animal unit' corresponds to one dairy cow, six calves or three yearlings.

\*\* The program is a joint venture between the Swedish Board of Agriculture, Sweden's County Administration Boards), the Federation of Swedish Farmers and a number of companies in the farming sector.





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Figure 31. Liquid natural fertilizer spread using a liquid manure spreader with tubes reduces ammonia losses, but even the best technique cannot hinder losses if the amount applied exceeds the plant uptake. The greater the density of animals on a farm, the greater the surplus of plant nutrients and consequent losses to the environment, which ultimately impacts on lakes and the sea.

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nitrites that are further transported to lakes and streams. Much of the ammonia and nitrous gases from the manure on intensive animal farms is lost to the atmosphere, but then returns to the land and water as nitrates through precipitation. Thus, it, too, ends up in the sea. Depending on variations in the weather from year to year, the volume of leakage may vary, with more leakage in wet years, and less in dry ones. Ongoing global warming is believed to lead to both more precipitation and increasing mineralization of previously organically bound plant nutrients in the soil.

### Phosphorus

In the case of phosphorus, the picture is more complex since phosphorus, more tightly bound to soil, is less mobile. Some phosphorus compounds, bound to particles of soil, are spread to lakes and streams through soil erosion. This means that several factors are at play: soil type, kind of vegetation, degree of disruption of the soil structure, and the technique used to spread manure all affect the outcome. The decisive factor with respect to the amount of phosphorus ultimately delivered to the Baltic

Sea, however, is the gap between the amount of phosphorus that has accumulated and the amount of phosphorus the crops on animal farms can make use of. Applying less phosphorus on specialized crop farms, which means less phosphorus in the soils there, makes no difference, for the losses to the Baltic Sea come mainly from animal farms with too high animal density, based on purchased fodder. Their production of manure and urine with both nitrogen and phosphorus far exceeds what the crops on the farm can make use of.

Figure 33 from a field study in Finland,<sup>26</sup> illustrates the factors at play. The study found that 50% of the phosphorus leakage in a watershed segment originated in less than 20% of the cultivated area. The area in question is the site of concentrations of livestock; phosphorus accumulates there year by year and is ultimately released to surface and groundwater systems.

**About 40 000 square kilometers of dead seabed**

The problem is further complicated by the fact that many countries are responsible for the nitrogen load from agriculture, sewage treatment plants and industry around the Baltic Sea. In the Kattegatt, both Denmark and Sweden and in Skagerak even an agricultural intensiv part of Norway share responsibility. Leakage from farms in Skåne and Halland in southwestern Sweden accounts for 80 per cent of all the nitrogen transported to

**Rehtijärvi lake drainage area, soluble P in top soil (mg/L) 1998**

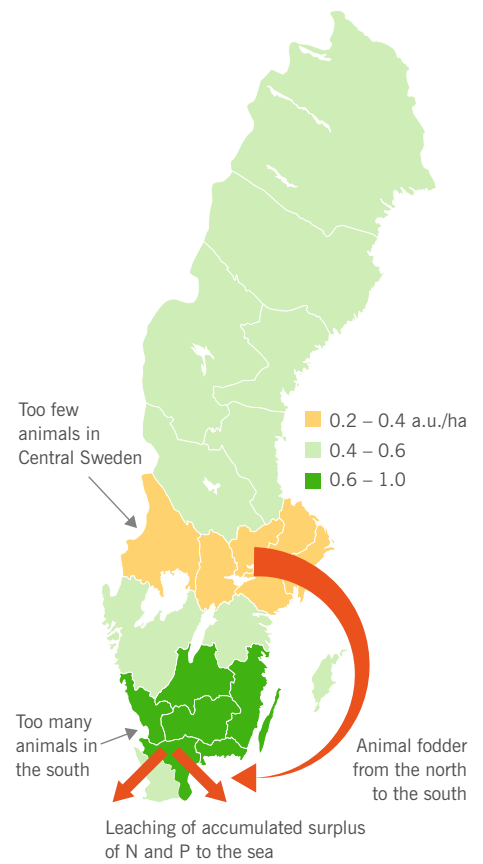
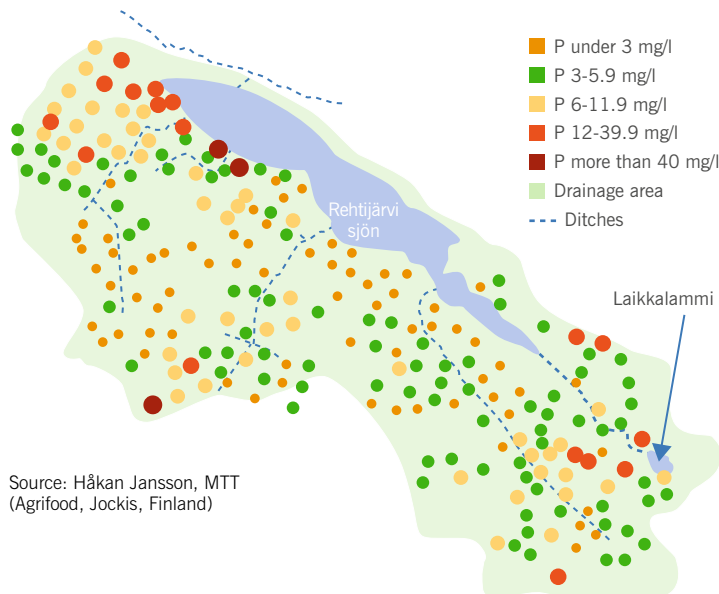


Figure 32. Regional concentration of livestock in southern Sweden, where leakage of nutrients is also greatest. Source: BERAS rapport nr 2<sup>25</sup>.

Figure 33 from a field study in Finland,<sup>26</sup> illustrates the factors at play. The study found that 50% of the phosphorus leakage in a watershed segment originated in less than 20% of the cultivated area. The area in question is the site of concentrations of livestock; phosphorus accumulates there year by year and is ultimately released to surface and groundwater systems.

<sup>25</sup> Granstedt, A Seuri, P and Thomsson, O (2004) Effective recycling agriculture around the Baltic Sea. Uppsala: SLU, Centrum for ekologiskt lantbruk. (Beras Report; 2).

<sup>26</sup> Uusitalo, R & Jansson, H (2002). Dissolved reactive phosphorus in runoff assessed by soil extraction with an acetate buffer. MTT Agrifood Research Finland.

the Kattegatt via rivers and streams. The average leaching of nitrogen from this part of Sweden is 40 kg per hectare and year – which is about four times the load at the end of the 1950s<sup>27</sup>. Further east, in the Baltic Sea south of the island of Gotland the main contributions come chiefly from southeastern Sweden, portions of Denmark and Poland. Further north in the Baltic, both Sweden and Finland share responsibility for the blooming algae, which has attained problematic proportions as far north as Åland and islands east and west of the archipelago, including the islands outside Turku. In the Gulf of Finland, the area of Russia around and east of St. Petersburg also contributes a considerable volume.

The resulting lack of oxygen in the Baltic Sea has led to a total or near-total absence of life on nearly half of the Baltic's seabed in recent years. Roughly 40 000 square kilometers. Temporary improvement is noted in some places some years, depending on variations in underwater currents, but overall, the situation is getting worse year by year. What is more, global warming is expected to worsen the situation due to greater amounts of precipitation in the Baltic Sea region, more mineralization of presently organically bound nitrogen and phosphorus in the land around the Baltic, and lower salinity in the sea.

“Baltic Ecological Recycling Agriculture and Society” (BERAS)<sup>28</sup>, a major research project financed in part by the European Union, documented flows of plant nutrients and plant nutrient surpluses in all eight EU Member States on the Baltic littoral in 1999-2002. The study found the greatest per hectare surpluses of nitrogen from agriculture that lead to pollution of the Baltic Sea in Denmark, followed by Sweden, Finland and Poland. More recently, a follow-up study, “Beras Implementation”, covering the period 2010-2013, has found that the nitrogen load from Poland has increased markedly, and in 2007 had reached nearly the same level as the load from Sweden (Figure 34). This increase, together with increases in Latvia, Lithuania and Estonia, amounts to a sizeable increase in nitrate pollution of the Baltic, despite the slight declines noted for Sweden and Finland and the more substantial decline in Denmark (Figure 35).

### **The environmental load – per hectare and overall**

When population size is factored into the equation, the nitrogen loads to the Baltic Sea from Sweden and Finland are greater than that from Poland. Otherwise, because of the country's size – with 16 million hectares under cultivation in Poland, compared to 2.6 million in Sweden – the total load from Poland is by far the greatest. Poland also has the highest losses of phosphorus. Surpluses and losses were low in Latvia, Lithuania and Estonia in 2000 after the countries' highly industrialized

<sup>27</sup> Andersson, R(1986). Förluster av kväve och fosfor från åkermark i Sverige [Losses of nitrogen and phosphorus from cultivated land in Sweden]. Uppsala: Sveriges Lantbruksuniversitet. (Dissertation)

<sup>28</sup> Granstedt, Seuri & Thomsson (2004). Effective recycling around the Baltic Sea. [www.jdb.se/beras](http://www.jdb.se/beras) (Beras rapport;2. Also: Sveriges Lantbruksuniversitet. Ekologiskt Lantbruk; 41.)

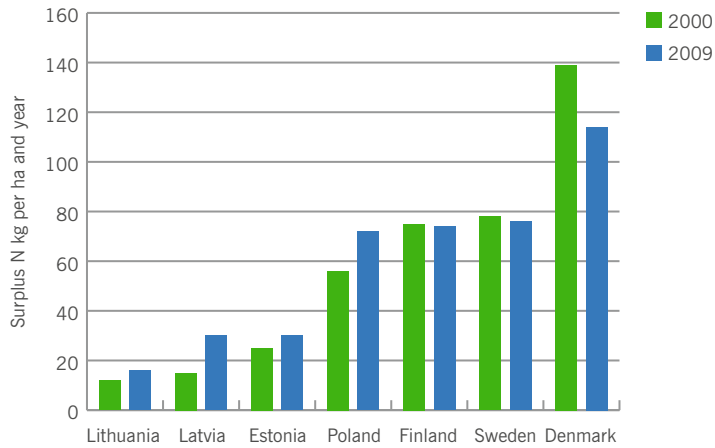
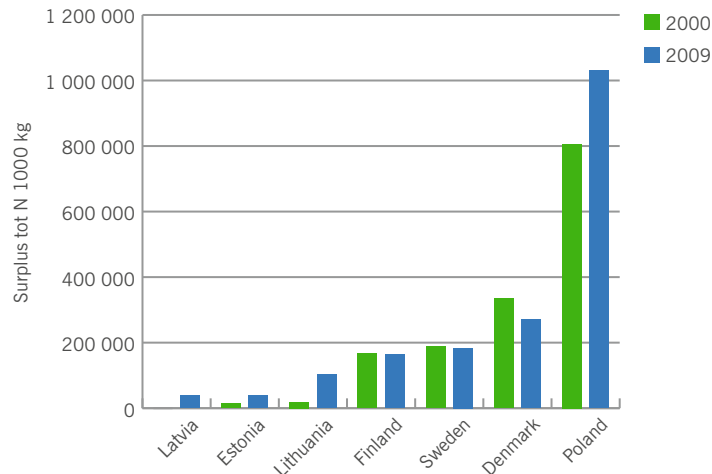


Figure 34. Nitrogen surpluses, kg N/hectare and year, in cropland in the respective countries around the Baltic Sea in the interval 2000-2009. Marked increases are noted in the Baltic states and Poland. The only country showing a notable reduction is Denmark, where the decline is from an extremely high level. This is due to a current nationwide program with the aim of achieving plant nutrient balance at farm level, with more efficient recycling of manure and urine. The slight reductions noted in Finland and Sweden have to do with increased areas of conversions to ecological farming methods, whereas levels remain unchanged in conventional agriculture. (Calculation based on current official statistics from the respective countries)



Figur 35. Total nitrogen surpluses within the Baltic Sea catchment area in the respective countries. Because of the country's extensive acreage, Poland has the greatest total surplus and leakage to the Baltic. (Calculation based on current official statistics from the respective countries)

agricultural collectives collapsed as a consequence of the dissolution of the Soviet Union.

Agriculture in these countries is getting back on its feet again, now on market terms and partly in the form of large-scale farms, with the help of European investors (Danish and Dutch in particular). In these cases, the specialized models that have characterized farming in Denmark, Sweden and Finland this past half-century have been introduced. This is the background to the increases in plant nutrient surpluses that have been noted since 2000. Poland still has considerable acreage in traditional small-scale farms as opposed to intensively farmed in the eastern and southern parts of the country, whereas to the west farming

**HELCOM Total waterborne nitrogen inputs by country in 2005**

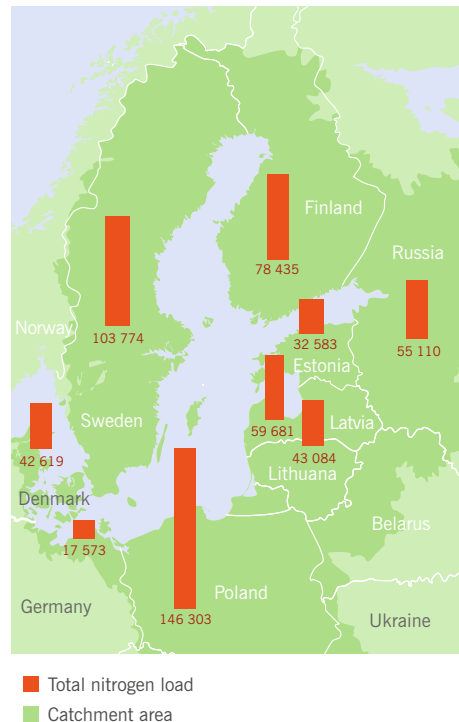


Figure 36. Water-borne nitrogen pollution of the Baltic (N tons) in 2005. Sweden is second only to Poland in terms of water-borne nitrogen pollution in the Baltic catchment area. Source: Helcom, PLC Group 2007.

continues on the scale established by the state-owned farms in the communist era, now on market terms. In the Petersburg region of Russia, large-scale meat-producing ‘factory farms’ and slaughterhouses are being established. Financed by interests in the EU and the USA, industrial agriculture has been introduced to some extent in all the Baltic states and in a few locations in Poland, as well<sup>29</sup>.

There is a clear risk that the root of the problem of nutrient losses in Sweden, Finland and Denmark may now spread and become dominant in all the countries around the Baltic Sea. The greater part of the grain produced with the help of increasing amounts of NPK fertilizer is used to produce feed, much of which goes to produce beef, poultry and pork. Other major users are large-scale dairy farms, with extreme numbers of cows. An increasingly one-way flow of plant nutrients runs from grain-producing farmland to increasingly intensive animal production. Additional plant nutrients come to intensive animal farming through imported feed, particularly soy protein from, for example, Brazil. The nutrients produced on these farms far exceeds what the crops there can absorb. These are the sites where the great annual nutrient surpluses accumulate; they are the prime source of leakage to the Baltic Sea.

The results of the BERAS project indicate that if the new EU Member States, Estonia, Latvia, Lithuania and Poland, rise to the level of nutrient losses that prevails in Sweden and Finland, the load of nitrogen leaked to the Baltic Sea would increase by more than 50 per cent. Studies undertaken by the Helsinki Commission (Helcom) agree.

**An objective never attained**

In Sweden an action plan to combat pollution of the seas was initiated as early as in the mid-1980s (“Hav 90”).<sup>30</sup> Under the auspices of

<sup>29</sup>The terms “factory farms” and “industrial agriculture” are used to describe installations with heavy concentrations of animals on an industrial scale, with no accompanying crop production. The scale and intensity of the installations do not permit free movement of the animals or grazing and little or no personal care of the animals. Feeding and maintenance of the animals are largely mechanized. In countries outside the European Union, antibiotics and other growth-promoting medicines are systematically administered in the feed. In the EU, a directive introduced in September 1996 (Council Directive 96/61/EC) stipulates that any such installation requires a special permit and inspections if it has more than 40 000 hens, 2 000 pigs, 750 sows or 400 cows.

<sup>30</sup>Naturvårdsverket (1990) Beredskap för akuta miljöhot mot havet [Sweden’s preparedness for acute threats to marine environments]. Rapport; 3698.

Helcom, all the countries around the Baltic Sea agreed to reduce their nutrient losses by 50 per cent by 1995, based on losses in 1987. The agreement was reached, then as now, without addressing the systemic error that is the root cause of nutrient losses from agriculture,<sup>31</sup> The surpluses of plant nutrients in conventional farming practices continued to increase.

The empirical evidence to date shows that symptom-focused measures alone do not lead to long-term reductions of nutrient losses. Tighter restrictions on manure and urine stores, regulation of the time at which manure is spread, more extensive cultivation of autumn-sown crops, and cultivation of catch crops will have no effect in the longer term as long as major annual surpluses of plant nutrients in the form of manure and urine continue to accumulate on animal farms, and the nitrogen and phosphorus from them continues to leak and pollute the surrounding lakes, rivers and sea (even groundwater in some areas), and the release of nitrogen compounds to the atmosphere.

The dire condition of the Baltic Sea today and the emergence of new threats in the form of more intensive farming methods in the eastern regions have precipitated a comprehensive set of measures to “save the Baltic”. Under the auspices of Helcom, the Baltic Sea Action Plan has engaged the governments of all the countries bordering on the Kattegatt and the Baltic Sea. The empirically documented history presented in the foregoing, however, gives reason to doubt that the programme will lead to any notable improvement – unless, that is, the governments also set about carrying out a fundamental reform of agricultural production systems throughout the region. The reform has to bring agriculture under the laws of Nature outlined earlier: circulation of plant nutrients in closed cycles based on integrated crop and animal farming.

Ministers for the Environment from all the countries around the Baltic convened in Krakow on 15 November 2007 to sign the Helcom Baltic Sea Action Plan, which sets out the common objective of reducing the total annual nitrogen load to the Baltic Sea by 135 000 tons (a 20 per cent reduction) and the phosphorus load by 15 000 (a reduction of nearly 50 per cent) by 2021. Each land has made specially tailored commitments (Table 1).

**HELCOM Total waterborne phosphorus inputs by country in 2005**

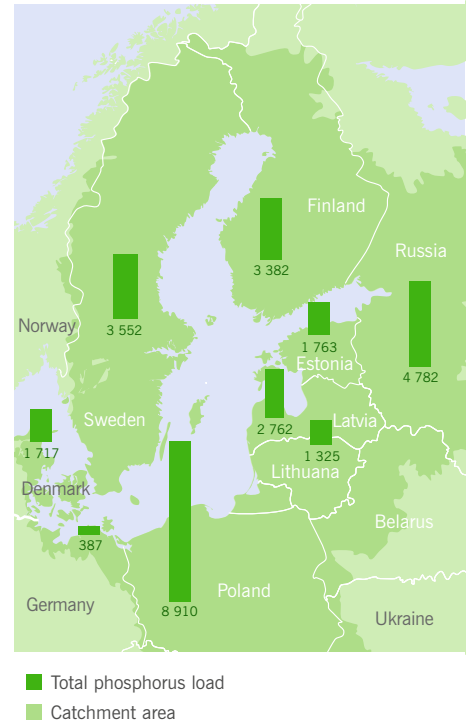


Figure 37. Water-borne phosphorus pollution of the Baltic (P tons) in 2005. Poland is the greatest source of pollution via streams and rivers in the Baltic catchment area. Russia comes second. Both countries lack fully efficient sewage treatment systems. Sweden, sparsely populated and relatively little cultivated, is the third-largest source of water-borne phosphorus compounds, however. Source: Helcom, PLC Group 2007.

<sup>31</sup> Naturvårdsverket (2003) Havet – tid för en ny strategi [The sea; time for a new strategy]. Havsmiljökommissionens betänkande. SOU 2003:72.



Table 1. Target reductions of phosphorus and nitrogen pollution of the Baltic Sea (in tons) on the part of signatories to the Helcom Baltic Sea Action Plan, adopted in November 2007. Source: Towards a Baltic Sea unaffected by eutrophication. Helcom ministerial meeting, Krakow, 15 November 2007.

The commitments the ministers for the environment made in Krakow in 2007 are to be harmonized with the EU Marine Framework Directive<sup>32</sup>, which envisions good ecological status for all European marine environments by 2021, and with the Water Framework Directive,<sup>33</sup>

	Phosphorus (tonnes)	Nitrogen (tonnes)
Denmark	16	17.210
Estonia	220	900
Finland	150	1.200
Germany	240	5.620
Latvia	300	2.560
Lithuania	880	11.750
Poland	8.760	62.400
Russia	2.500	6.970
Sweden	290	20.780
Transboundary Common pool*	1.660	3.780

\* Leakage that cannot be attributed to any given country.



The commitments the ministers for the environment made in Krakow in 2007 are to be harmonized with the EU Marine Framework Directive, which envisions good ecological status for all European marine environments by 2021

which took effect throughout the Union in 2000. The Water directive stipulates that maximum loads of nutrients shall be determined for every stream or body of water in the Union. An annex with recommendations for the agriculture sector sets out the principle that spreading of manure shall correspond to the amounts that crops can make use of.<sup>34</sup> The only specific limit is that set out in the Nitrates Directive that took effect in 1991.<sup>35</sup> The Nitrates Directive limits the amount of nitrogen spread in the form of manure to a maximum of 170 kg N per hectare and year, which is four times as much as the amount spread on ecological farms that practice recycling. Despite the generous limit that, what is more, only applies to manure, several EU Member States have applied for, and been granted, exemptions that allow animal farms to spread as much as 200 hg nitrogen per hectare and year.

<sup>32</sup> European Parliament and Commission (2008) Marine Strategy Framework Directive. Directive 2008/56/EC. Published in Official Journal of the European Union L 164/19/EC (25.6.2008).

<sup>33</sup> European Parliament and Commission (2008) Marine Strategy Framework Directive. Directive 2008/56/EC. Published in Official Journal of the European Union L 164/19/EC (25.6.2008).

<sup>34</sup> Helcom (2007). Recommendation 28E/4, adopted 15 November. Revised Annex III, Part II: Prevention of pollution from agriculture.

<sup>35</sup> European Council of Ministers (1991) The Nitrates Directive. Council Directive 91/676/EEC, 12 December.

The Swedish Board of Agriculture has calculated how much plant nutrient losses would be reduced if all the currently known measures – catch crops, storage of manure, regulated times for spreading fertilizer, wintergreen fields, reduced tilling, and restoration of wetlands – were actually implemented.<sup>36</sup> According to the Board's calculations, the maximum reduction in nutrient losses would be 3 335 tons of nitrogen and 22 tons of phosphorus, to be compared to the commitments made under the Helcom Baltic Sea Action Plan: nearly 21 thousand tons of nitrogen and 290 tons of phosphorus.

Even if it is possible to reduce effluents from sewage treatment plants and private sewage systems, much more must be done before the Helcom commitments can be reached. Most of the measures cited in the Board of Agriculture's report have short-term effects. They imply accumulation and storage of the nutrients in the soil for a limited time. Furthermore, their effectiveness may be undermined by global warming. In long term reduced losses can be achieved through reduced application. This in turn can only be achieved through more effective recycling of nutrients within the country's agriculture.

Instead of the proposals that have been put forward to reform Swedish agriculture in the direction of ecological recycling, the Board carries on a discussion that implies the discontinuation of cultivation in favor of permanent grassland in vital areas of the country. Similar ideas have been put forward in Finland.

Should these proposals be realized, agricultural production will most probably be reduced, and the import of food products will instead increase, which means that the environmental consequences of conventional farming systems will be exported.

The results of the EU-financed BERAS program (2003-2006) and preliminary findings from BERAS Implementation (2010-2013) have been presented to authorities and policy-makers in all countries.



What is more, most of the measures cited in the Board of Agriculture's report have only short-term effects. They imply accumulation and storage of the nutrients in the soil for a limited time only. Furthermore, their effectiveness may be undermined by global warming

<sup>36</sup> Jordbruksverket (2008) 64 åtgärder inom jordbruket för god vattenstatus [64 measures in agriculture for better water status]. Rapport; 2008:31.



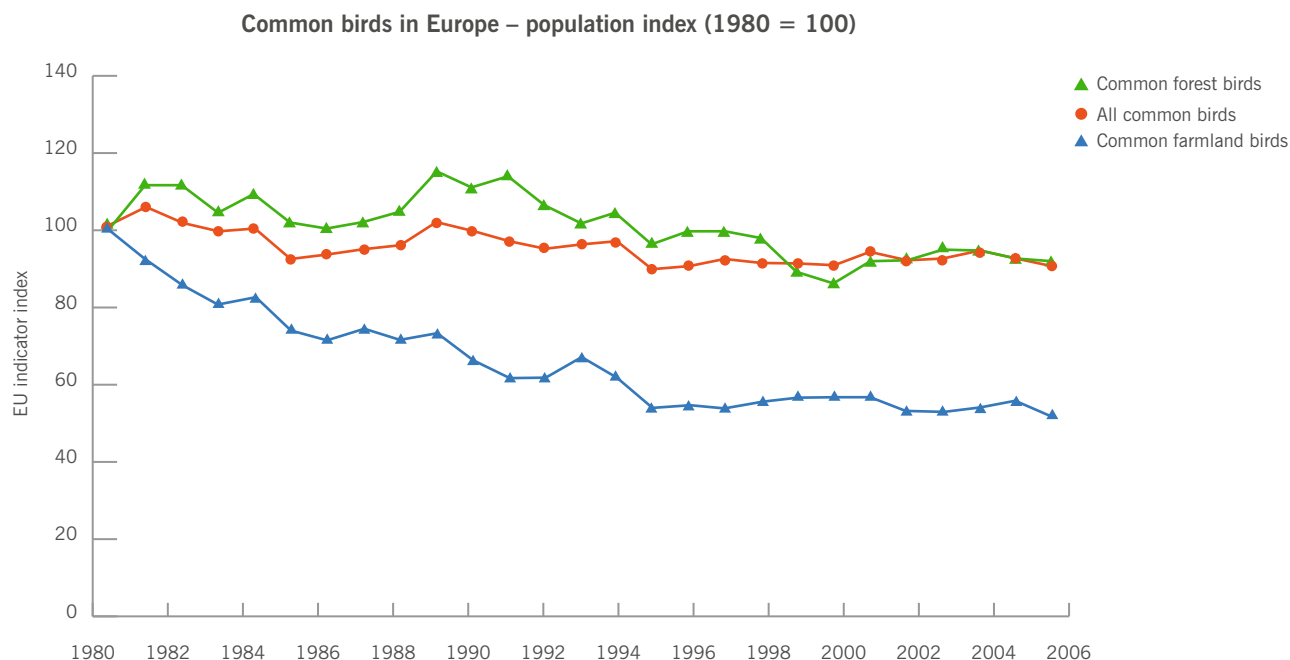
### The spread of toxins in the environment

Sweden's Environmental Quality Objective, No. 13:

*"The value of the farmed landscape and agricultural land for biological production and food production must be protected, at the same time as biological diversity and cultural heritage assets are preserved and strengthened."*

Until rather recently, farms all over the country raised a variety of crops with intermittent periods of annual and perennial ley crops including grass and legumes in rotation. These practices hindered the propagation of pests and weeds that 'specialized' in various crops. The introduction of chemical fertilizers, however, made it possible to produce a single crop, generally grain, on farms without accompanying herds and flocks and without cultivated pasture. This led to mounting problems with invasive weeds as well as pests. Increased application of nitrogen, often in excessive doses, in the early phases of growth also renders the cultivated plant more susceptible to fungi. Cell membranes are softer, and the young plants have larger leaves, are taller and leafier, characteristics that facilitate the spread of fungus and make it easier for fungal hyphae to penetrate into plant tissue. Plants' vulnerability to insect pests increases, too. Increasing damage to crops, disease, pests and weeds,

Figure 38a Overall, Europe's common bird populations reduced by around 10 % since 1980. Common farmland birds declined most severely (around 50 %) but common forest birds also declined by some 9 %. Falls have levelled off since the late 1990s. Europe's grassland butterflies have declined dramatically (60 %) since 1990 and this reduction shows no sign yet of levelling off. Data source: EBCC/RSPB/Bird Life International/Statistics Netherlands, 2008.



all due to improper methods of cultivation, has led to an increase in the use of chemical toxins – fungicides, pesticides and herbicides – that parallels the trend in use of synthetic fertilizers.

Chemical analysis and biological testing have detected residues of pesticides in food. Through laboratory tests on animals, authorities believe they have established limit values for these residues that eliminate hazards to human health. They say they have weighed the risks against the benefits when authorizing the use of these toxins in agriculture. Many previously approved chemicals are today forbidden due to environmental and health concerns. Those who were suspicious of their safety have been proven right.

If we look to the relative hazard of different agricultural toxins, pesticides that affect the nervous systems of insects are particularly problematic. These toxins are widely used to protect oil crops. Conversion to so-called 'low dose' pesticides only means that the toxin is more concentrated, i.e., more toxic per gram. Pyrethroids like deltamethrin are toxic at concentrations several orders of magnitude under the level of detectability in water tests. These toxins are also break down slowly and can accumulate in biological systems.<sup>37</sup> The cited research suggests the possibility that poisons that kill insects by attacking their nervous system may also affect the human nervous system and the brain. The combined effects of different toxic residues is a poorly researched area, as well. The limit values for different toxic compounds are established considering the hazard posed to human health by each compound individually. The lack of research on so-called "cocktail" effects has only recently been recognized as a problem. In real life we are affected by the sum of many different chemicals, and some of them may have mutually reinforcing effects. Without conclusive research the question remains open.

Recent years' field research has found major negative impacts on both flora and fauna since the introduction of pesticides into the cultivated landscape. Populations of some bird species have been reduced by as much as one-half in agricultural areas, a decline that is associated with a general decline in biodiversity and changes in patterns of land use. The existence of different kinds of plants that go to seed at different times is important to bird life. Fields of organically grown crops host a greater variety of plants (which, when in excessive numbers, are called weeds) that in turn host beneficially predatory insects. Some weeds have

### EU indicator index common agriculture birds



Figure 38b. The long-term trend is worst for farmland birds. The figure shows the trend for farmland birds in Sweden, corresponding to the Farmland Bird Index adopted by the European Union. The baseline is 2002. The values noted, which go back to 1975, are based on so-called free point routes. Source: Åke Lindström and Martin Green, University of Lund, Biodiversity and Conservation Science.

<sup>37</sup> Adolfsson, T & Reslow, C (2005) Underlag för uppdatering av kontrollprogram för bekämpningsmedel i vattendrag [Base data for the revision of control programs for pesticide residues in surface water]. Lunds universitet, Ekotoxikologi II.

even been shown to improve the growth, harvests and quality of crops. Even more far-reaching environmental impacts may be expected if we set out genetically modified organisms.

### 'Low-dose'?

There are a number of so-called 'low-dose' herbicides on the market today. They are called 'low-dose' because only a few grams per hectare yield the toxic effect of several kilograms of, for example, phenoxy acid – the reason being, of course, that the active substance is much more toxic. The claim that use of these toxins represents a "low dose" can be misleading. The volume of toxic fluid spread over fields has declined, due to reduced dosages and conversion to 'low-dose' compounds. But if we look to the area treated with toxic chemicals (hectare doses) in Sweden, we find a slight reduction between 1982 and 1992, but a resumed increase thereafter. Total use of pesticides has increased by over 60 per cent since 1990, despite the fact that organic cultivation, which uses no pesticides, has increased from 3 per cent of the total area under cultivation to 19 per cent, from 80 to nearly 500 thousand ha (Figure 39a). Use of toxic chemicals has more than doubled (an increase of 125%) on land farmed using conventional methods. Use of pesticides in Finland has also risen (Figure 39b); the same is true in Estonia, Latvia, Lithuania and Poland.

Hectare doses of pesticides in Sweden 1991-2008

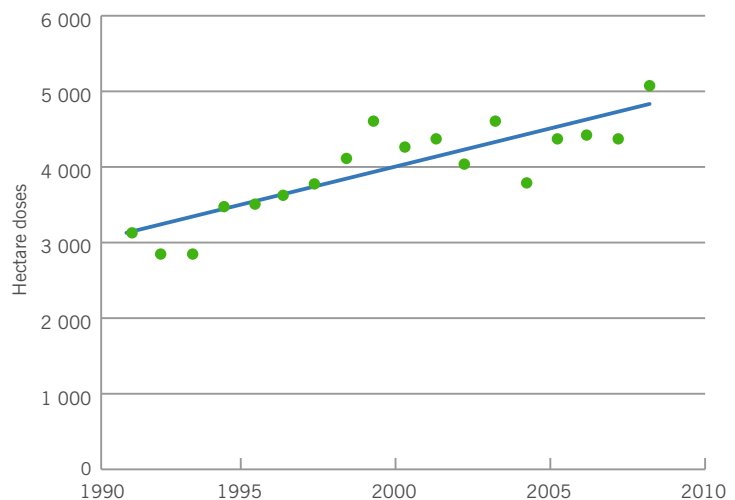


Figure 39a. Hectare doses of pesticides in Sweden 1991-2008. Source: Statistics Sweden. Jordbruksstatistisk årsbok 2010 [Yearbook of Agricultural Statistics 2010].

Thus, the idea that farmers use less pesticides today as a consequence of greater risk awareness and more efficient technology is patently false. At the same time, there is considerable empirical documentation that shows that it is entirely possible to raise crops with good yields without any of these chemicals. The growing acreages under organic cultivation are the proof. Farmers can quit spreading pesticides in the environment if they convert to a system based on promoting biodiversity (through varied crop rotation and raising companion plants), mechanical pest control, soil management technique, and rational use of organic fertilizers.

### Cadmium pollution is still with us

A special problem is the accumulation of cadmium in cultivated land due to many years' application of phosphorus fertilizers, which contain cadmium. The cadmium content of grain raised on intensively farmed soil is particularly high. Despite changes to fertilizers with less cadmium content, cadmium continues to accumulate on land where levels are already too high. Use of sludge from sewage treatment plants as a fertilizer and to enhance productivity increases the load of cadmium along with the other hazardous substances – pesticide residues, antibiotics and other medicines, hormone-altering chemicals, etc. – that sewage sludge contains. The microbial life in the soil is disrupted, and cadmium in our food is known to reduce bone density and stress the kidneys. Recent research

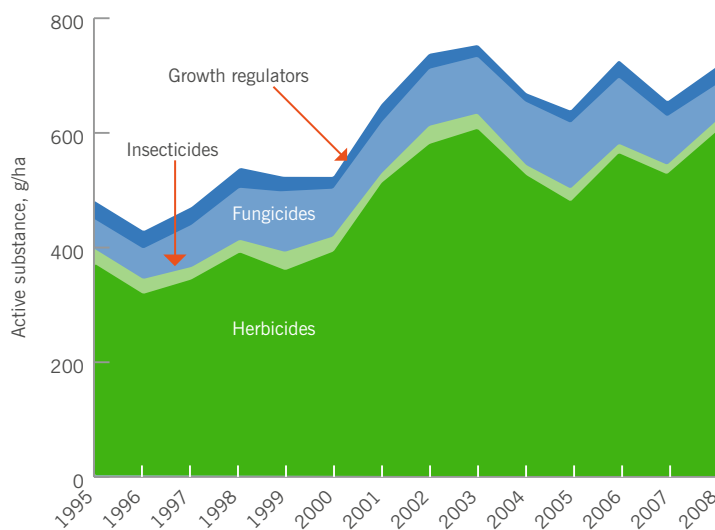


Figure 39b. Average use of pesticides and growth regulators in Finland (expressed in g active substance) 1995-2008. Source: Finland. Ministry of Agriculture and Forestry. Information Centre.



About 70 per cent of all pig production takes place in facilities having more than 750 animals; the pigs cannot move freely, let alone go out of doors. They have no opportunity to root in the soil, wallow in mud or any of the things pigs do

also raises suspicions that cadmium may also cause cancer of the uterus and prostate gland. In light of these findings EFSA, the food safety authority of the European Union, in March 2009 lowered the 'tolerable weekly intake' (TWI) of cadmium by nearly two-thirds: from 7 to 2.5 micrograms per kilo body weight. Half of the population of Europe are believed to consume more than this amount even today.<sup>38</sup> There is also fear that the cadmium content of phosphorus fertilizers is on the rise.

### Cruelty to animals

Specialization of farming has led to ever-larger and more concentrated installations where poultry and pigs are raised.

About 70 per cent of all pig production takes place in facilities having more than 750 animals; the pigs cannot move freely, let alone go out of doors. They have no opportunity to root in the soil, wallow in mud or any of the things pigs do. Those who tend the pigs in the stalls are forced to don both face masks and ear plugs, whereas the pigs are forced to live their entire lives without such protection in an extremely stressful environment, with tremendously high decibel levels and feed dust in the air. Many pigs suffer from inflammations of the lung. Despite this harsh reality, Swedish pork production is 'marketed' as humane – with pictures of happy pigs with curly tails – compared to even worse conditions in other countries.

Recently, news of extreme cruelty to pigs in the Danish pork industry reached the public: sty boxes that are so small that they both wound and cripple the pigs; no straw; amputated tails – all for the sake of cheap pork and bacon, much of which for export. Ultimately, it is we consumers and ethically sensitized purchasing managers who have the power to reform the industry and put an end to these cruel practices.

Media attention to the problems of mass production of animals and routine administration of antibiotics in feed has brought about some improvements. For example, it is now forbidden within the EU to administer antibiotics in feed; antibiotics are now subject to prescription. Sweden was a leader in this development. Sweden notes considerably less incidence of antibiotics-resistant bacteria in animal husbandry than in several other comparable Member States.<sup>39</sup> Despite of that there reports of use of too much antibiotics in animal production, and warnings that prescribing antibiotics to sows may promote antibiotics-resistance that might be transmitted to humans.

<sup>38</sup> EFSA (European Food Safety Authority). Press release from a research conference held on 30 March 2009 at Lund University in the framework of PHIME (Public health impact of long-term, low-level mixed element exposure in susceptible population), a EU-financed research program.

Confinement in cages and on limited floor space implies a severe limitation of the birds' freedom of movement and all possibility of their living a normal hen's life, which, furthermore, is a violation of the general animal welfare law. Some 95 per cent of Sweden's 5.3 million laying hens live in populations of 5 000 hens or more, and many of these installations are operated by 'companies' that have no cropland.

The average Swedish poultry breeder raises 85 000 chicks at a time, and can manage about seven cycles a year. Chickens are slaughtered at the age of 32-39 days, when they reach a gross weight of about 1.7 kg (net weight: 1.2 kg). In their brief lifetimes they have consumed 3 kg of chicken feed. The ratio of meat to feed is very favorable and has been held forth as an advantage from the point of view of climate change. Instrumental breeding and more effective nutrition have hastened rates of growth, which translates into cheaper poultry, but there is a dark side, as well. About 15 per cent of chickens sent to slaughter suffer some form of damage to the skeleton that can be attributed to the speed of their growth. The organism simply cannot keep pace with the weight gain curve. Some young chickens die of heart attacks. If they were allowed to live longer than a month, they would soon die of ill health. If we believe that chickens can experience suffering, the price of cheap poultry is high indeed. And, we have every reason to believe that chickens do suffer. Anyone who keeps pets and other animals knows how they express vigor, joy and sadness.

There is some debate about the extent to which chickens experience suffering. Studies of animal behavior indicate that they do suffer to varying degrees. Be that as it may, clearly, our way of raising laying hens and poultry is a far cry from the natural conditions under which mother hens, famously, care for their young. Machine-incubated and crowded together, they are treated as no more than industrial products under conditions that few consumers are aware of.

### **Grazing animals are better off – but their lives, too, are short**

Milk cows have a better life, albeit here, too, the scale of production is increasing. They are able to move about; many graze freely a good part of the year. The average milk cow, however, has a shorter life span than cows under natural conditions – only five years, about one-third of the natural life span of a cow. Milk cows, too, are put under considerable stress to produce the greatest possible volume of milk in their short lives.

<sup>39</sup> Statens Veterinärmedicinska Anstalt (SVA) (2008). Årsredovisning 2008 [Annual report of the Swedish National Veterinary Institute 2008].



Animals with only one stomach – like pigs and fowl – eat products that people might eat

They are fed grain, supplemented with soy protein, a much richer diet than a cow's ruminating stomachs are cut out for. Roughly half of all antibiotics administered in animal husbandry are used to treat mastitis, inflammations of the udder, which one Swedish cow in five suffers at some point in her life.

Perhaps the most animal-friendly form of food production is raising cattle and sheep that graze on open range. The feed-meat ratio is low, but the animals mostly eat grass and other vegetation that human beings cannot digest. Grazing also produces food from land that is not suitable for cultivation, at the same time keeping it clear of shrubs and sapling trees. Animals with only one stomach – like pigs and fowl – eat products that people might eat. In ecological terms one might say they compete with us for nutrition.

Viewed from the point of view of the environment and global resources, most of the feed that is transformed into poultry meat might better be consumed by human beings directly. In Sweden roughly 25 per cent of the feed in poultry production is soy protein imported from South America, where large-scale cultivation of soy contributes to global deforestation. In a world with successively more mouths to feed and a shrinking resource base, it is wrong to feed a growing share of the planet's protein-rich crops to animals, when it might instead nourish people.

Under these circumstances meat and dairy products should be produced by cud-chewing animals that eat what human beings cannot, namely, the grass and clover that make up ley. These plants also play an essential role in crop rotations, restoring and building up the mulch content in the soil. As noted earlier, continuous production of grain depletes mulch. Indeed, proper management of the world's soil organic biomass reserves requires that we, even in areas specialized in the production of grain, reintroduce periods of ley cultivation with restorative grasses and legumes like clover and lucerne. To remain fertile, land that has experienced slow, but sure humus depletion under many years needs to replenish its organic substance. Periods of ley production have the added advantage of serving as carbon sinks, reducing emissions of greenhouse gases.

Certainly, animals with only one stomach have a place in agrarian ecosystems – but under entirely different and far more humane conditions and on a smaller scale. Their role is to make use of all the waste that we humans produce: spilled seed and plant remains after harvest (birds are phenomenally effective scavengers) and left-over food (pigs thrive on it). Grazing cattle play a fundamental role in northern agriculture, where conditions are ideal for the cultivation of grasses and clover. Feeding cows protein-rich seeds will in all probability soon be seen for

what it is: a waste of vital resources. We shall return to the subject of what our food choices – the crops we produce and the food we eat – mean for the environment and the climate in a later chapter.

**From energy producer to energy consumer**

The central role that agriculture once played, using sunlight to create new resources, is no more. As recently as the 1950s, agriculture was a net producer of energy. By cultivating legumes, farms satisfied their own nitrogen needs through symbiotic nitrogen fixation, and fields and meadows produced the ‘fuel’ that horses needed to work the land. The solar energy stored in biomass supplied a significant share of the energy used in the rest of society, as well – until coal, and then oil and gas ushered in the industrial age. By the 1970s, modern farming practices had transformed Swedish farms from net producers of renewable energy into major consumers of energy from finite sources.<sup>40</sup> The same transformation has taken place throughout Europe, albeit to somewhat varying degrees.

Tractor fuel, heating, the energy used to manufacture machinery, synthetic fertilizers, imported feed, etc., today use more energy than the energy value of the food products the farm produces. The balance may be expressed either in energy units (megajoules) or CO<sub>2</sub> equivalents (Figures 40 and 41). The production of one kilo of chemical fertilizer requires 1.5 liters of oil; what is more, present fertilizer production technology emits nitrous oxide (a.k.a laughing gas), a powerful climate-changing agent. (More advanced technology that reduces this side-effect is coming into use.) In Denmark, which imports vast amounts of feed, the energy balance is even more out of kilter.

Figure 41 shows the climate impacts in the form of greenhouse gas emissions from Swedish agriculture. In addition to the emissions noted in the table we have the methane that cows emit. These latter emissions are balanced, however, by the humus-generating grassland on which the cattle graze. Grassland binds the carbon in the humus formed, thereby actively counteracting global warming.<sup>41</sup> Products from animals that mainly feed on imported grains and soybeans, on the other hand, contribute to the depletion of the world’s humus reserves. More on this

<sup>40</sup> Resursflöden i svenskt jord- och skogsbruk 1956 and 1972 med tonvikt på energiströmmar. Rapport från en arbetsgrupp tillsatt av Kungliga Skogs- och Lantbruksakademien. [Analysis of the resource flows in Swedish agriculture and forestry 1956 and 1972, with particular attention to energy flows: Report of a working group appointed by the Royal Swedish Academy of Agriculture and Forestry] (1975) Uppsala: Lantbrukshögskolan, Institutionen för ekonomi och statistik. Rapport; 64.

<sup>41</sup> Soussana, J F, Klumpp, K & Tellec, T (2009) Mitigating livestock greenhouse gas balance through carbon sequestration in grasslands. IOP conference series, Earth & Environmental Sciences 6 : 242048 <http://iopscience.iop.org/1755-1315/6/24/242048>. Soussana, J F et al. (2007) Full accounting of the greenhouse gas (CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>) budget of nine European grassland sites. Agriculture, Ecosystems and Environment 121: 121-134.

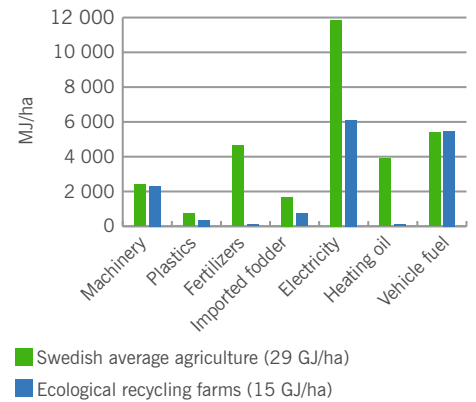
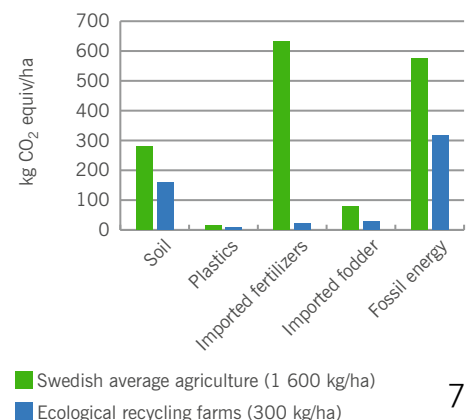


Figure 40. Use of energy resources (MJ/ha) in Swedish agriculture (total average) and in Ecological Recycling Agriculture. Source: Thomsson et al. (2005).

Figure 41 Shows the climate impacts in the form of greenhouse gas emissions from Swedish agriculture. In addition to the emissions noted in the table we have the methane that cows emit. These latter emissions are balanced, however, by the humus-generating grassland on which the cattle graze. Grassland binds the carbon in the humus formed, thereby actively counteracting global warming. The annual emissions was calculated 997 kg eq per ha in the conventional agriculture and 1 380 kg per ha in the ERA agriculture. Grassland for ERA farms was calculated to be 40 % higher compared to the conventional. Products from animals that mainly feed on imported grains and soybeans, on the other hand, contribute to the depletion of the world’s humus reserves. More on this in the chapter on the environmental consequences of our diet choices.





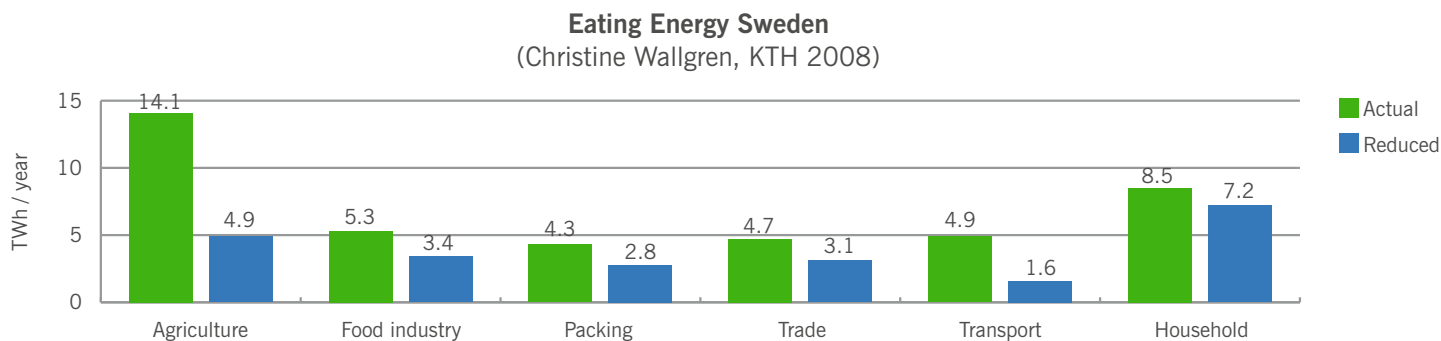
in the chapter on the environmental consequences of our diet choices. In the future, agricultural production has to be based on ecologically sound cultivation techniques that use considerably less energy. This is discussed later in conjunction with Ecological Recycling Agricultural systems, but the diagrams above reveal some striking contrasts between ‘conventional’ and ERA farms.

Figure 41 shows the energy use of all the links in the so-called ‘food chain’. The net per capita climate impact of people in Sweden has been estimated to add up to approximately 10 tons, expressed in CO<sub>2</sub> equivalents (Figure 42). A review of the literature performed at the request of the Swedish Environmental Protection Agency indicates that food consumption (‘from crop to shop’) represents no less than 28 per cent of that total (Figure 44).<sup>42</sup> In addition, there is the impact of yearly deforestation of land that is then used to produce feed commodities, like soybeans, and some food products, primarily for export. This yearly decrease in the carbon stored in biomass increases the amount of carbon (in the form of CO<sub>2</sub>) in the the atmosphere. The added contribution of food transports and cooking brings food’s total share of the per capita climate impact can be estimated to 45-50 per cent.

It should be noted that roughly 20 per cent of the climate impact indicated in Figure 43 refers to consumption of beverages, tobacco and other items that are not actually food. As a guide to ‘climate-friendly eating habits’ statistical summaries like this can be misleading. As we shall see in the following, the decisive factor is the nature of the agricultural system in which food is produced. Even dairy products and beef can be ‘climate-smart’ choices if they come from cows that feed on clover grass instead of cereal and soya. Grassland with clover and grass production build up the humus layer—and thereby the ‘climate sink’ capacity of the soil. Cereal production without a crop rotation that includes clover and grass use up the organic biomass in soil. The climate impact of agrarian Sweden before fossil energy began to be used was negligible. Agriculture was 100 per cent solar-powered and provided food, clothing, raw materials and draft power to the rest of society based on renewable energy sources. In the not too distant future agriculture will once again assume this role using modern technology.

<sup>42</sup> Naturvårdsverket (2008) Konsumtionens klimatpåverkan [The climate impact of consumption]. [www.naturvardsverket.se/sv/Klimat-i-forandring/Konsumtion-och-klimat/Konsumtionens-klimatpaverkan](http://www.naturvardsverket.se/sv/Klimat-i-forandring/Konsumtion-och-klimat/Konsumtionens-klimatpaverkan). FOI, Totalförsvarets Forskningsinstitut (2008) [Review of the literature on the climate impact of Swedish consumption].

Figure 42. Use of energy in the food chain, present (2008) and target reductions of 60%, expressed in TWh/yr. In 2008 agriculture accounted for 34% of the total. Source: Wallgen (2008).



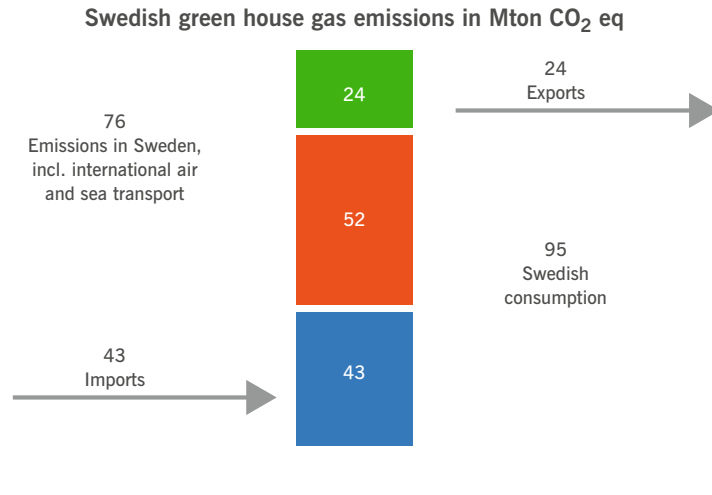


Figure 43. Greenhouse gas emissions in Sweden in 2008 amounted to roughly 10 tons per capita, taking account of the fact that emissions of imports to Sweden are greater than the emissions attributable to Swedish exports. Source: Naturvårdsverket (2008)

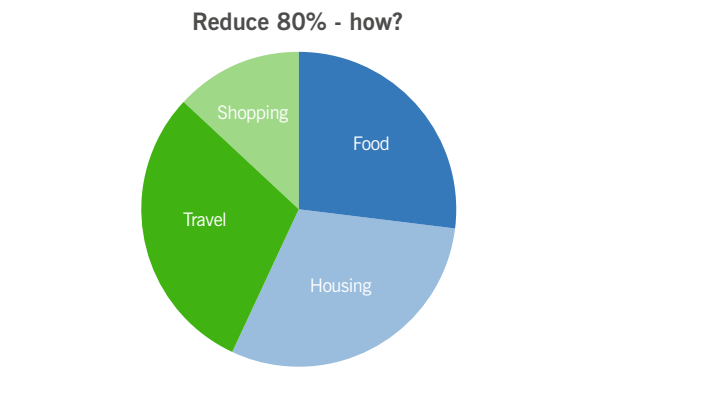


Figure 44. Greenhouse gas emissions from our food consumption is calculated to 28 % of the total climate impact per capita in Sweden. Source: Naturvårdsverket (2008). But in this figure is not the effects of deforestation for food and feed production and indirect effects of our food consumption for the private food transportation, private storing of food in our homes and cooking which in this figure are including in the other sectors.

**Swedish greenhouse gas emissions (CO<sub>2</sub> equivalents, millions) attributable to consumption of food, drink, tobacco and restaurant dining**

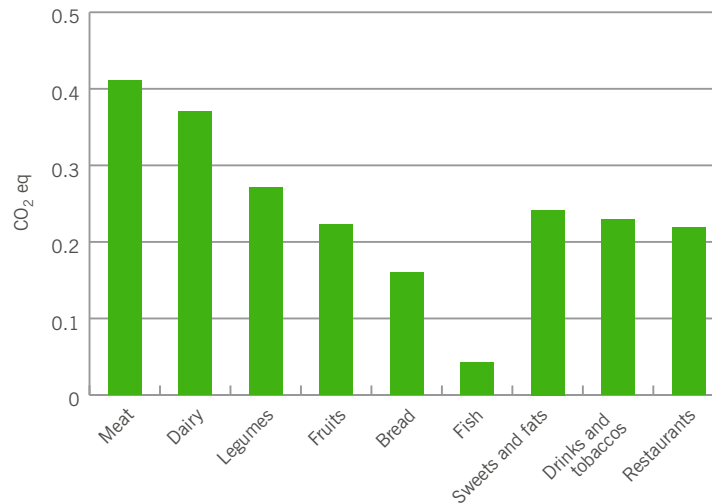


Figure 45. Food, drink and tobacco (from cultivation to retail outlet) account for roughly 25% of total per capita emissions of greenhouse gases in Sweden (approx. 10 tons CO<sub>2</sub>e/person). When the energy used to prepare food in households, canteens/cafeterias and restaurants, plus the share of deforestation in the tropics for the purpose of food production are included, the share rises to about 40% of the total greenhouse gas emissions per capita, Source: Naturvårdsverket (2008).

## **THE ALTERNATIVES – BIODYNAMIC, ORGANIC AND ECOLOGICAL AGRICULTURE**

**Ecological agriculture is about more than technical solutions to practical problems. It is also about how we think about our relationship with Nature and living beings.**

In the 1950s in Sweden an alternative movement emerged and took its place alongside conventional agriculture. The oldest of these alternative schools of thought, biodynamic cultivation, was elaborated by Rudolf Steiner, an Austrian, in the 1920s; the first Swedish biodynamic farms were established in the late 1940s.

Another alternative school, called organic-biological cultivation, is based on the ideas about cultivation techniques introduced in Switzerland by Hans Müller, a medical doctor, and H P Rausch, a microbiologist, in the 1940s. Organic-biological farmers pay particular attention to the microbial life in soil and its importance for productivity and nutritional quality.

In England, what we know as organic farming practices were introduced by Sir Albert Howard – he, too, a medical doctor by training. Howard is especially known for a composting technique (the Indore method), inspired by traditional Indian techniques that he became familiar with as a colonial officer and Head of the Institute of Plant Industry in Indore in the 1920s.

The term “ecological agriculture” does not refer to any specific method. Instead, ecological agriculture should be understood as a movement or project leading toward specific objectives: to achieve sustainability in agricultural production and to produce crops, animals and animal products of high quality. The principles of biological recycling, the interplay of a wide variety of living organisms, and renewable energy sources are all in focus. As in the case of so-called “eco-villages”, “eco-communities” and terms like “human ecology”, ecological agriculture extends beyond techniques and technology to embrace the needs and values of human beings. In short, ecological agriculture is a new way of thinking about our relationship to Nature and the vast spectrum of living beings.

Modern organic agriculture draws increasingly on the results of publicly financed experimentation, but also on the practices and experience of a couple of generations of organic farmers. Organic farmers worldwide share the same principles, and they collaborate through IFOAM (International Federation of Organic Agricultural Movements). Today (2009), IFOAM has 750 member organizations in 108 countries. Organic farmers’ core values are summed up in the following principles:

### Principle of health

*Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.*

### Principle of ecology

*Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.*

### Principle of fairness

*Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.*

**Principle of care:** *Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.*<sup>43</sup>

### A Nordic green platform

On the basis of IFOAM's norms for Organic Agriculture, in 1986 the Nordic chapter of IFOAM formulated the following definition, philosophy and goals for Organic Agriculture:

*Definition.* Organic Agriculture is a self-sustaining and sustainable agro-ecosystem that is in balance. The system relies, as far as possible, on local and renewable resources.

*Holism and ethic.* Organic Agriculture is based on a holistic view that includes ecological, economic and social aspects of agricultural production in both local and global perspectives. In Organic Agriculture, Nature is seen as a whole, having its own value, and human beings have a moral responsibility to farm the land in such a way that the cultural landscape is a positive feature of the environment.”

*The following goals were set out:*

- produce food of high quality, in sufficient quantities and fairly distributed;
- economize with natural resources and minimize negative environmental impacts;
- recirculate nutrients to the greatest possible extent;
- maintain the cultivated landscape, its diversity of species and genes;
- maintain the long-term fertility of the soil;
- keep flocks and herds in ways that allow the animals to live according to their instincts and needs; and
- give the farmer a reasonable income, pleasure in his or her work, and a safe working environment.

As a consequence of the goals of maintaining biodiversity, economizing with natural resources, and avoiding negative environmental impacts,



In short, ecological agriculture is a new way of thinking about our relationship to Nature and the vast spectrum of living beings

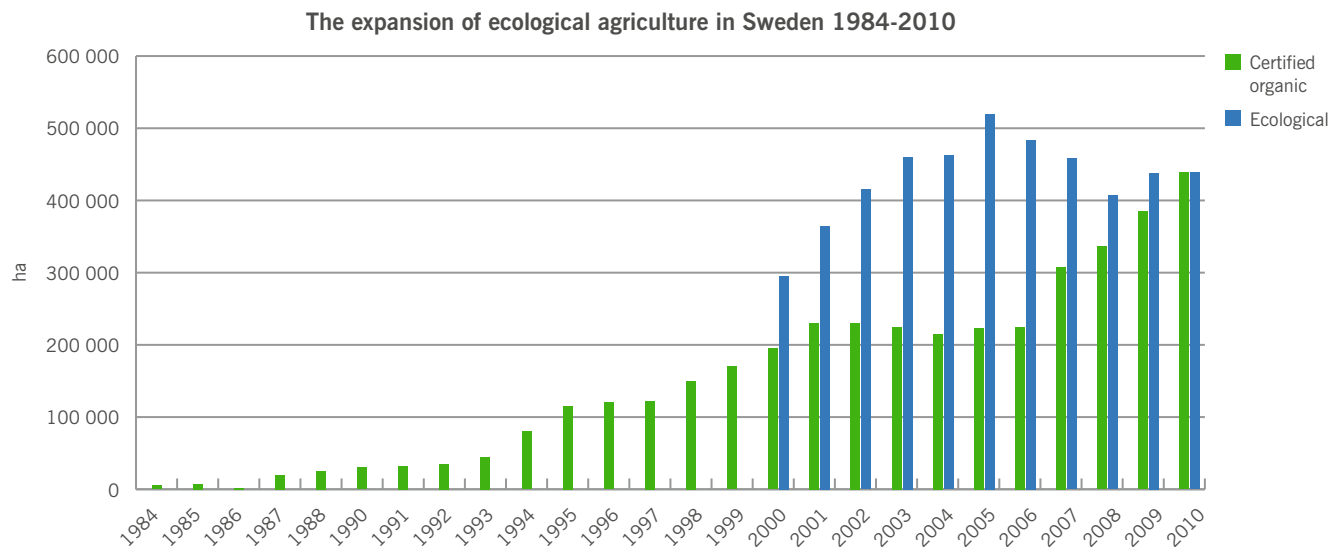
<sup>43</sup> IFOAM. Principles of organic agriculture. [www.ifoam.org/about\\_ifoam/inside\\_ifoam/organization.html](http://www.ifoam.org/about_ifoam/inside_ifoam/organization.html).

ecological or organic agriculture uses no chemical pesticides or industrially manufactured mineral fertilizer (synthetic fertilizer).

### The breakthrough

The 1980's witnessed a major breakthrough for organic farming in Scandinavia and Finland. Of these countries, the trend has developed most rapidly in Sweden, where acreage increased from about 1 500 ha (0.05% of Sweden's total farmland) in 1980 to 33 000 ha (1.0%) in 1990, to 120 000 ha (> 4% of the 2.8 million ha under cultivation at the time) in 1997 (Figure 46). In 2010, 439 000 ha, or 18 per cent of Sweden's cultivated farmland was certified organic (KRAV).<sup>44</sup> After the findings of two major government studies – the Committee on New Guidelines on Chemicals Policy (Kemikalieutredningen) of 1982-1985 and the report of the Commission on the Environment and Natural Resources in 1983 (SOU 1983:56) – had been presented, Sweden introduced targeted levies on synthetic fertilizers and chemical pesticides. Government support to research on organic farming was introduced in 1986, as were government agricultural advisory services in so-called 'alternative' techniques. Today, a broad assortment of organically grown food products is available in Sweden's three main chains of retail outlets in the food sector. The demand for such products outstrips supply. What has not developed as quickly or strongly are research and advisory

Figure 46. Ecological agriculture has expanded markedly in Sweden in recent decades. Cultivated acreage that qualifies for EU's environmental compensation (ECO) now amounts to nearly 20 % of total arable land. Many farmers who raise organic crops have their products certified, by KRAV and/or the Demeter labeling system, as a guarantee to consumers.



<sup>44</sup> For information on the Swedish certification system, KRAV, and the criteria for certification, see [www.krav.se/System/Spraklankar/In-English/KRAV/](http://www.krav.se/System/Spraklankar/In-English/KRAV/).

services. Appropriations in these two areas have not kept pace with the actual expansion of organic farming. The Faculty of Natural Resources and Agricultural Sciences at the Swedish University of Agricultural Sciences (SLU) has not yet, despite the urging of the organic farming sector, created any department for ecological or organic agriculture, nor are there courses in Agronomics that specifically focus on organic methods. The idea, says the University, is that ecological practices will be included in all curricula in all the departments.

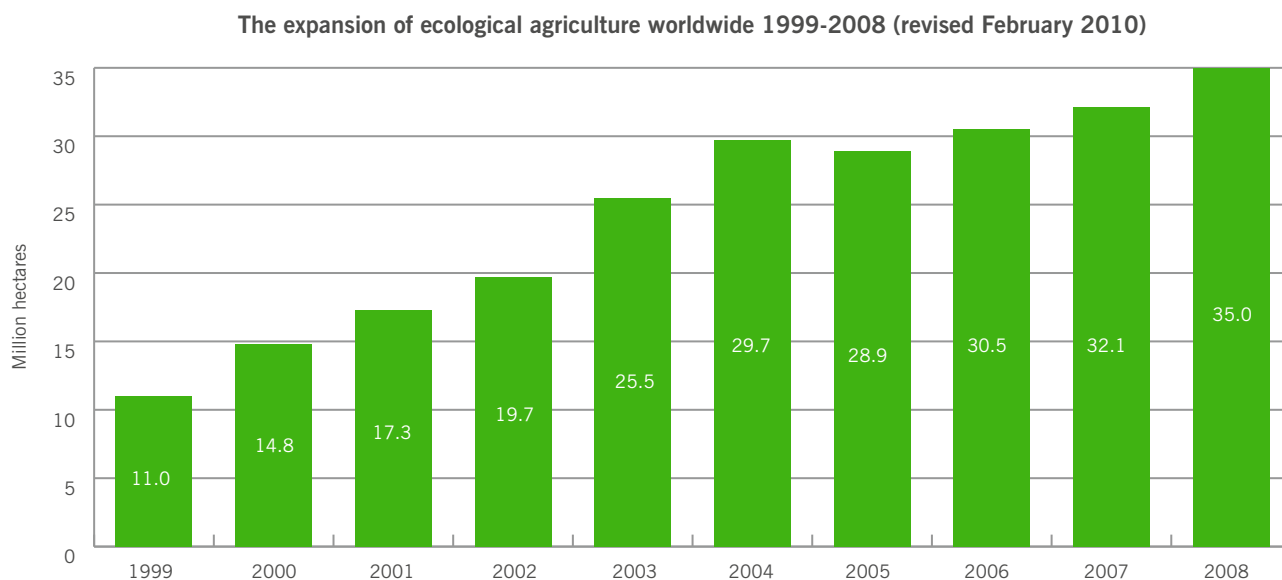
The trend has been similar in many parts of Europe, with countries like Germany, Austria, Switzerland, Sweden and Finland leading the trend. And the sector continues to grow worldwide (Figure 47). In Sweden, the government and parliament set out a goal of “20 per cent organic in 2010”. The prime motive behind this objective is that they saw organic agriculture as an important means by which to fulfill the country’s national Environmental Quality Objectives.

In the 1950s, 1960s and 1970s research in organic agriculture was undertaken under the auspices of a number of privately financed, not-for-profit research institutes. In time, research projects got under way in some European universities. In Sweden, agronomist Bo Pettersson did pioneer work at the facilities of Nordisk Forskningsring in Järna. Pettersson’s work may be said to have laid the foundation for biodynamic

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*Figure 47. Total acreage under organic cultivation expanded from 11 million ha in 1999 to 35 million ha in 2008. This is somewhat more than 2 % of all arable land (2 400 million ha). Source: FIBL, Research Institute of Organic Agriculture (2010).*

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The term “ecological production” refers to a number of different farming systems, of which biodynamic farming is the most distinctive

and organic agriculture in the Nordic region.<sup>45</sup> The first Swedish doctoral dissertation that compared what was then called ‘alternative’ farming with conventional methods was approved in 1981 of Josef Dlouhý. It was based on field trials carried out simultaneously in Järna and at SLU under the supervision of Bo Pettersson, with financing from Ekhaga-stiftelsen, a foundation formed by a private donator who was deeply interested in biodynamic farming. The study found modest differences in yield between conventional and organic methods (5-20 per cent lower yields for organic methods overall).<sup>46</sup> At farm level, differences can be greater, due to the conversion to organic methods. On the other hand, substantial differences in favor of the organic products were found in the areas of nutritional quality and storage properties.

#### The rules

The certified food products sold on the market in Sweden today have been approved by an organization known as KRAV and may bear the “KRAV” label. Products that, furthermore, meet the criteria for biodynamic farming may bear the “Demeter” label, as well. In addition to the internationally agreed principles and goals outlined above, there are also numerous detailed specifications and rules of conduct that apply to different products and classes of products that the grower pledges (in writing) to observe. Inspections at the farm and product control are not performed by KRAV itself, but by independent certification organizations. The term “ecological production” refers to a number of different farming systems, of which biodynamic farming is the most distinctive. Biodynamic certification includes the requirements that the farm must always combine animal and crop production and that certain compounds developed within the biodynamic movement shall be used to enhance both plant life and the microbial and other life in the soil.

<sup>45</sup> Dlouhy, J. (1981). Alternativa odlingsformer –växtprodukters kvalitet vid konventionell och biodynamisk odling. Avhandling. Sveriges Lantbruksuniversitet, Uppsala.. (Alternative agriculture – crop products quality in conventional and biodynamic farming, Dissertation. Swedish University of Agriculture)

<sup>46</sup> Pettersson, B.D. (1982) Konventionell och Biodynamisk odling, jämförande försök mellan två odlingsystem. Nordisk Forskningsring. Meddelande 32, Järna. (Conventional and Biodynamic Farming, Comparing experiments between two farming systems. Nordic research circle. Report 32, Järna Sweden)



## GOALS WITHIN REACH – THE BERAS PROJECT

Were the Baltic states and Poland to introduce conventional agricultural as practiced in Sweden today, it would increase the nitrogen load on the Baltic Sea by more than 50 per cent. If the countries instead convert to Ecological Recycling Agriculture, the load will be cut in half, and phosphorus surpluses will be a thing of the past.

In 2003, BERAS (Baltic Ecological Recycling Agriculture and Society), a research project financed in part by the European Union, involving 48 farms in all eight EU Member States around the Baltic Sea, got under way. The project compared conventional agricultural practices and including the recently very important criteria for such farming, recycling, organic farming, termed 'Ecological Recycling Agriculture' (ERA), the principal characteristic of which is combined animal and crop production, in which the number of animals on the farm is limited to the amount of fodder the farm can produce. The 48 participating farms were selected so as to represent the variety of growing conditions that exist in the region (Figure 48). The project lasted three years, 2003-2006, and was coordinated from the Biodynamic Research Institute in Järna, Sweden. Fifty researchers from universities and research institutions

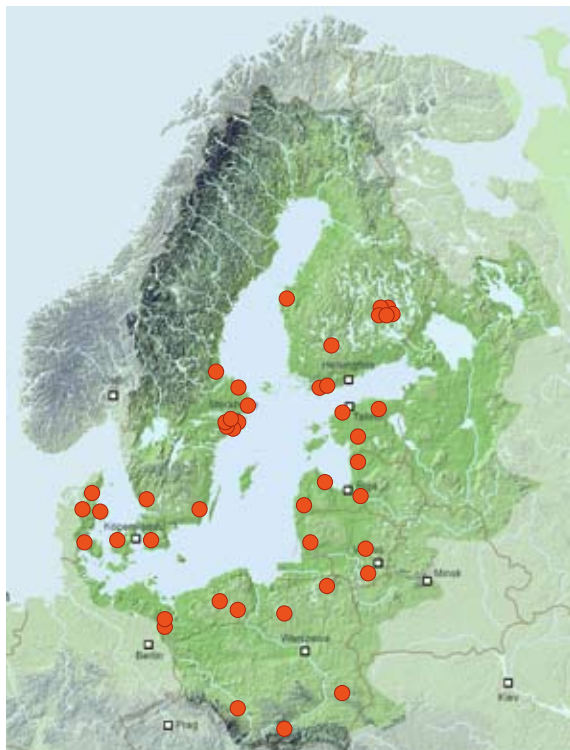


Figure 48. Map indicating the 48 ERA farms in Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Germany (the Baltic littoral) and Denmark that participated in pilot studies within the BERAS (Baltic Ecological Recycling Agriculture) project. Part of Russia proper and the Russian enclave, Kaliningrad, are also part of the Baltic's catchment area, but no farms in these territories participated in BERAS pilot studies. Partners and farms in Russia and Belarus are included in the new BERAS Implementation project, however.

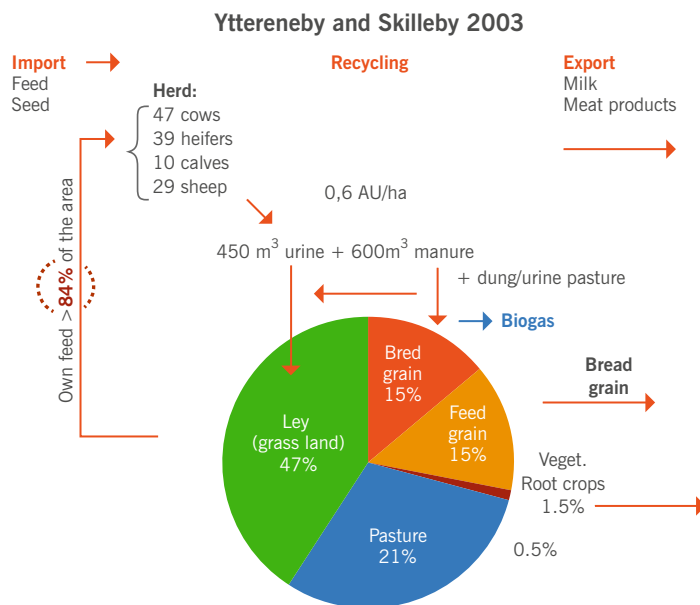
### BERAS-project 2003–2006

- 20 partners from 8 countries
- Pilot studies on 48 farms
- Nutrient balances
- Leakage measurement
- Energy and global warming potential
- Consumer surveys

throughout the region were involved. Studies evaluated the farms' climate impact, leakage of plant nutrients to the environment and impacts on biodiversity. Studies of economic and social aspects were also included. The methods and findings of the project have been reported in seven reports published by the Swedish University of Agricultural Sciences (SLU) and in a number of refereed scientific papers.

All the participating farms observe the basic principles outlined at the outset of this book: solar-based renewable energy sources, biological recycling and maintenance of biodiversity. Human intervention in the environment ensures that food and other goods of good quality are produced in sufficient quantity within the framework of fundamental ecological principles. It should be noted that this is the way agriculture was practiced until well into the twentieth century, when modern, input-demanding practices broke the rules.

Figure 49. Flows of plant nutrients and biomass on an ecological recycling farm with the number of animals. The amount of animals and the animal production on this farm (Yttereneby-Skilleby in Järna, Sweden) is adapted to the farm's production of own fodder. Source: BERAS (2009).



### A model ERA farm

#### Yttereneby – Skilleby Farm in Järna

The number of animals is adapted to the fodder produced on the farm: 84 % of the cultivated acreage is used to produce fodder, and 16 % produces for the market. The animal density is 0.6 AU/ha, which is average for Sweden and Europe, given current patterns of meat consumption.

Arable land	ha		Crop rotation
Crop rotation	106	Year	1 Spring cereals + insowing
Pasture	29		2 Ley I
Vegetable -			3 Ley II
root crops	2		4 Ley III
<b>Total</b>	<b>137</b>		5 Winter cereals
Natural pasture	25		

Farms that operate according to the basic ecological principles are self-sufficient in both fodder and fertilizer. This is ensured by the fact that each farm, or farms in collaboration, keeps no more animals than can be fed with home-grown fodder. Between 60 and 90 per cent of all nutrients that the feed crops absorb is then recycled to the soil in the form of manure. Nitrogen needs are satisfied by cultivation of legumes – as was the case before synthetic fertilizer was introduced (Figure 46).

**In the BERAS project, each participating farm had the following:**

1. Diversified crop rotation with a large enough share of ley including legumes to satisfy the system's nitrogen requirements through biological nitrogen fixation, and no use of synthetic fertilizers or chemical pesticides. In the case of the BERAS farms, this meant at least one-third of the crop rotation was ley (grass and clover), corresponding to 50 per cent of the cultivated area, grazing included. More than half the animals' feed was in the form of grass and legumes instead of grain and soy imports.
2. Mixed production of crop products (mainly bread grain) for the market and animal production in proportion to the farm's fodder production in order to ensure the greatest possible degree of recycling of nutrients, while avoiding plant nutrient surpluses through purchases of nutrients in the form of feed products. On average, this translates into 0.6 animal units per hectare, with manure production corresponding to a maximum of 50 kg nitrogen per ha – less than one-third of the amount allowed by Helcom and the EU Nitrates Directive.

**Not a question of turning back the clock**

The distribution of crops on Skilleby Biodynamic Experimental Farm (Figure 49) is representative of the average of the 48 ERA farms. As shown in the figure, 84 per cent of the cultivated land is devoted to growing fodder for a number of animals that is adapted to the farm's production capacity: 47 milk cows, 39 young cattle, 10 calves and 29 sheep in 2003. The rest of the land produces crops like bread grain and potatoes and some vegetables in amounts representing the average in agriculture. The distribution of land use corresponds to present-day consumption patterns, in which meat is the prime source of protein. *The ecological recycling model does not imply a return to the farming practices of yesteryear; it means using modern techniques and knowledge to manage one's farm in harmony with fundamental ecological principles.*<sup>47</sup>

<sup>47</sup> Granstedt, A, Seuri, P & Thomsson, O (2008). Ecological Recycling Agriculture to reduce nutrient pollution to the Baltic Sea. *Journal of Biological Agriculture and Horticulture* 26: 297-307.

### Ecological Recycling Agriculture

- Economizing with finite resources and reduced loss of nutrients by adapting animal production (0.6–0.8 animal units/ha) to the farm’s capacity to produce fodder, so that most of the nutrients can be recycled;
- Self-sufficiency in nitrogen through biological nitrogen fixation (crop rotation with legumes as ‘green fertilizer’);
- Preservation of biodiversity and the soil as a resource through diversified crop rotation, ley cultivation, and no use of chemical pesticides.

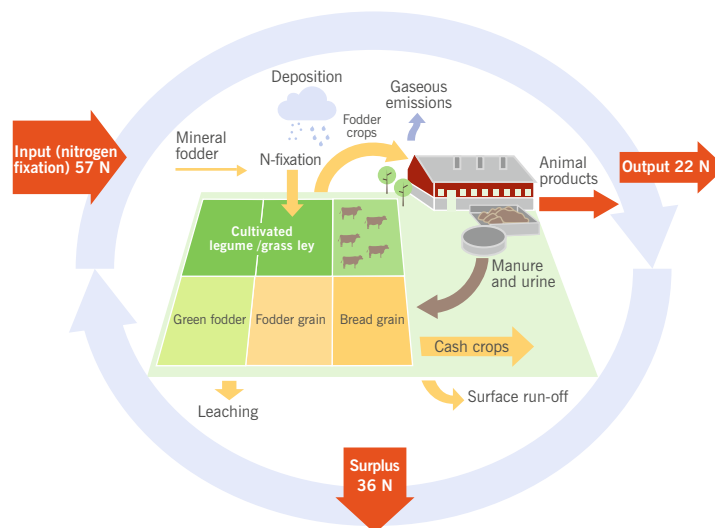


Figure 50. Simple diagram of nitrogen flows on an ERA farm: Small amounts of nitrogen flowing to the farm and maximum recycling of plant nutrients produce the least possible nutrient losses. This high degree of recycling can be achieved by adapting the number of animals on the farm to the farm’s capacity to produce fodder and using legume-based ley production in the crop rotation. The result is a 50 % reduction in nitrogen surpluses and 70-75 % lower leakage of nitrogen than in conventional farming practices. The high share of clover grass in the crop rotation also has the consequence of building carbon store in organic matter in soil. (Detailed nutrient balance is presented in figure 2 in the supplement).

The estimated average nitrogen surplus of all Swedish farms was 79 kg/ha and year in 2002-2004; the average for the twelve Swedish BERAS farms was 36 kg/ha and year (Figure 49). Total animal production in this comparison is the same in conventional agriculture as in organic agriculture (0.6 animal units per ha); the difference is that on the BERAS farms, animals are spread out over the land according to each farm’s capacity to produce fodder. This prevents the accumulation of unused manure, the cause of nutrient surpluses. Ammoniac losses are the same for equal numbers of animals, but the surplus that pollutes the soil and, ultimately, the Baltic Sea is 70-75 per cent lower on the BERAS farms.<sup>48</sup>

This comparison, calculated per ha arable land in use, applies to Sweden, but is essentially the same for Finland. In the Baltic countries the situation is different due to relatively low levels of production and as yet low inputs, and thus smaller losses. Organic farming of the kind described here would mean higher production with small losses. Figure 50 illustrates the choice before farmers in the Baltic Sea region today.

<sup>48</sup> Larsson, M & Granstedt, A (2010). Sustainable governance of agriculture and the Baltic Sea: Agricultural reforms, food production and curbed eutrophication. *Ecological Economics* 69:10, (15 August, ISEE).

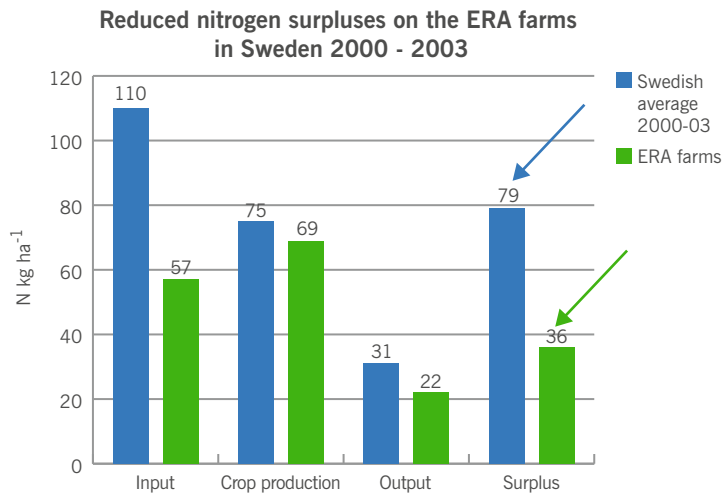


Figure 51 Ecological Recycling Agriculture farms in Sweden have 50 % lower nitrogen surpluses per hectare than the average conventional Swedish farm. Harvested vegetable biomass was 8 % lower than the average conventional farm (expressed here as kg N/ha). All in all, agricultural production from the farm in animal and crop products combined was 30 % lower because of the considerably higher share of clover – grass land based fodder-based meat in the ecological alternative. Source: BERAS 2003-2006 (2009)

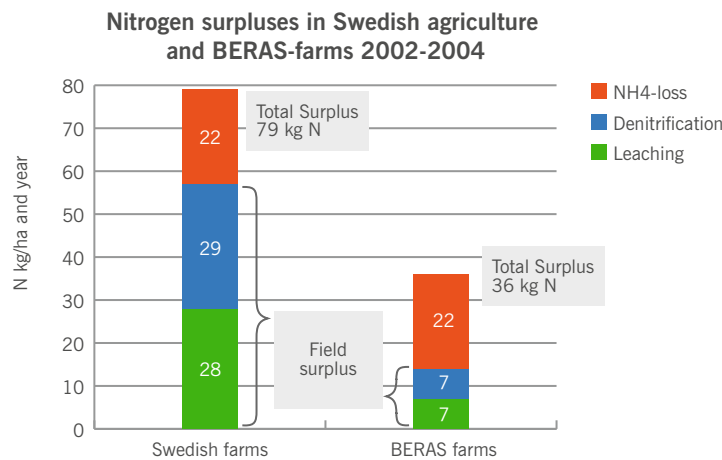


Figure 52. If we exclude losses in the form of ammoniac, which are roughly the same in both conventional and ecological agriculture, the remainder gives us a measure of the losses from the soil. The lower values for BERAS farms mean that nitrogen leakage there is 70-75 % lower than in modern conventional agriculture, given the same density of animals. Source: BERAS 2003-2006 (2009).

The results indicate 70-75% lower leakage of nitrogen from BERAS-farms compared to the conventional agriculture.

### Three scenarios for average field surplus of nitrogen from agriculture in the Baltic Sea region, based on the BERAS studies

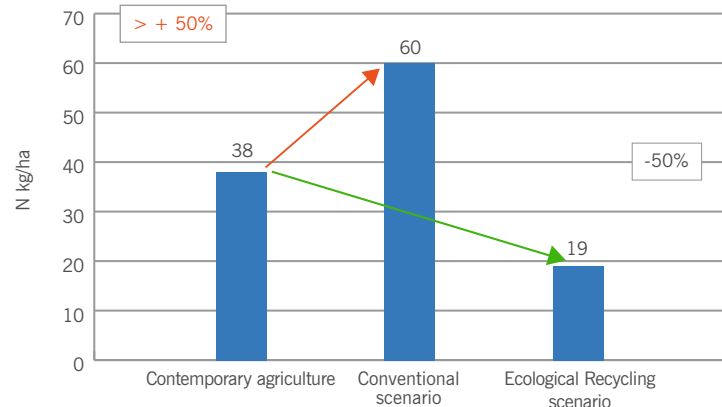


Figure 53. The results of the BERAS project included three scenarios: 1) The present nitrogen load, which demands immediate action to save the marine environment in the Baltic Sea; 2) expansion of the conventional agricultural practices in Sweden into the Baltic states and Poland, which would mean a > 50 % increase in the total load; 3) conversion to Ecological Recycling Agriculture in accordance with the results from the 48 farms that participated in the BERAS trial studies would mean a 50 % reduction in the load and no surplus of phosphorus. Source: Granstedt et al (2008).



Figure 54a+b. Long-term field trials on all fields at Skilleby ERA farm. The experiments compare the effect of different programs of organic fertilization in the context of a five-year crop rotation: Oats with insowing, Ley I, Ley II, Ley III, followed by Winter wheat. The comparisons focus on composted vs. non-composted manure at three levels of application, and the effects of selected compounds used in biodynamic cultivation. The effects studied are the long-term effect on soil fertility, harvests, and product quality. The map illustrates the five basic elements in agriculture: miscellaneous structures, housing, and stalls for the animals; garden farming centrally located; tilled fields on which crop rotation between nourishing and extractive crops is practiced; cultivated pasturage and natural meadows for grazing; and forests for fuel and timber. The map also shows a posted path for self-guided tours around the farm, experimental plots and the natural features of the farm landscape (The map was drawn by Gottfried Geiger, a pioneer and prize-winning biodynamic farmer and adviser, in 1996.)

### Fertility can be restored

The humus layer in the soil is the product of thousands of years of vegetation, the organic remains of which provide the raw material for humus-generating processes. Cultivation breaks off these processes, and existing humus decomposes. The cultivation of new land around the world is believed to have reduced the land's original organic carbon reserves in the form of humus by as much as 60 per cent in temperate regions and over 75 per cent in the tropics. As described in earlier chapters, it is entirely possible to halt the degeneration of humus by using organic fertilizer and cultivating humus-generating legumes. Unfortunately, this is not always done, particularly not in areas where grain and other commodities are grown using mineral (synthetic) fertilizers. Large areas around the world have lost their fertility through improper farming techniques; to compensate the loss, new land is often cleared by clear-cutting forest.

Our cooler climate here in the North slows down the process of humus degradation. The introduction of cultivation of ley with grass and leguminosis in the early 1800s brought about a restoration of existing farmland and a gentler use of new parcels brought under cultivation. Care for the soil through cultivated ley and recycling manure continued into the 1950s as a fundament for all agriculture, but the positive spiral was broken here in the North when some farms began to grow grain exclusively. This development was particularly common in mid-Sweden and southern Finland, where few flocks and herds are kept today.

As the humus is depleted, the soil gradually loses its capacity to hold water and nutrients, and the life in the soil declines. As a result the farmer becomes even more dependent on soluble fertilizers, and the soil becomes increasingly difficult to plow and work, requiring more and more powerful and heavy machinery. As a result topsoil is packed together, and a negative spiral has got under way.

In 1958 field trials started that compared the effects of mineral and organic fertilizers under controlled conditions for no less than 32 years.<sup>49</sup> The study found that a biodynamic farm managed according to the principles of Ecological Recycling Agriculture can in the course of a few decades restore the humus layer by an average 900 kg carbon per hectare and year. Alongside this longitudinal study several shorter experiments confirmed the results. Similar results have been reported from several studies elsewhere around the world.

<sup>49</sup> Granstedt, A & Kjellenberg, L (2008) Organic and biodynamic cultivation: A possible way of increasing humus capital, improving soil fertility and being a significant carbon sink in Nordic conditions. Second Scientific ISOFAR Conference, Modena, Italy, 18-20 June.

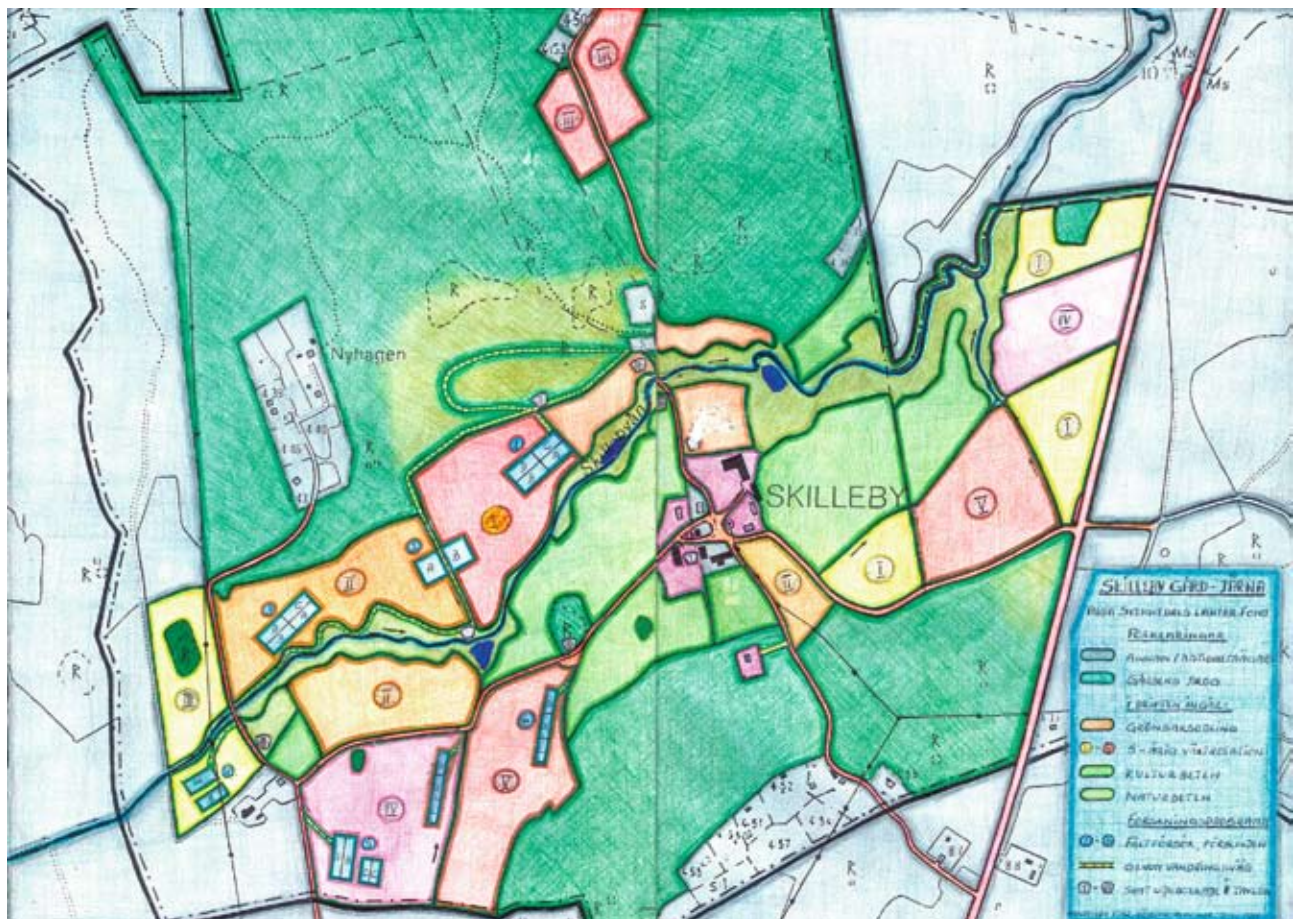


Since 1991, a second longitudinal comparative study is in progress under the supervision of the author (Figure 54). Here, an entire farm, Skilleby Experimental Farm in Järna, is involved. After three completed crop rotations we note a significant increase in humus in the topsoil (0-20 cm), amounting to 400 kg carbon per hectare and year (Figure 52). The increase has proven to be markedly greater when biodynamic methods and composting are used. Samples of the subsoil show that humus is generated even deeper than expected, so that the total amount of carbon accumulated in the humus approaches one ton per hectare, which corresponds to 3 500 kg of CO<sub>2</sub> equivalents. Animals at Skilleby are fed on a fodder-based diet (grass and clover), and composted manure is returned to the soil. Ley with clover and grass is cultivated in three of the five stages in the crop rotation, the humus-generating effects of which have been documented in a special experiment on ley cultivation at the farm.<sup>50</sup>

”

As described in earlier chapters, it is entirely possible to halt the degeneration of humus by using organic fertilizer and cultivating humus-generating legumes

Figur 54c.



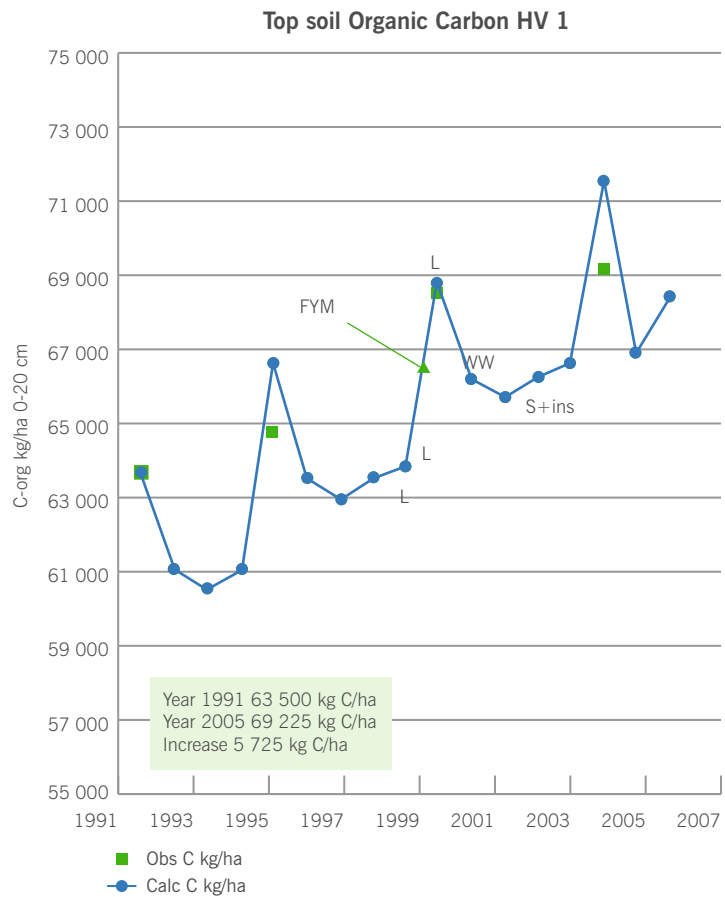
<sup>50</sup> Granstedt, A & L-Bäckström, G (2000) Studies of the preceding crop effect of ley in ecological agriculture. *Journal of Alternative Agriculture* 15:2:68-78.



### Legumes do double duty

In years to come, food from ERA farms that cultivate ley with legume and grass will reduce the impact on the climate. In addition, the CO<sub>2</sub> emissions from use of synthetic fertilizer will be eliminated. Cultivated legume-rich ley does double duty: it binds atmospheric nitrogen through photosynthesis and a symbiotic relationship with bacteria, and it helps to build up a carbon sink in the form of humus, *directly* in the form of harvest waste and decomposing root systems, and *indirectly* through the recycling of nitrogen via the digestive systems of the animals it feeds.

Figur 55. Results of the fertility experiment at Skilleby. Observed (green dots) and model-calculated (blue dots) values on parcel HV1: organic carbon in the soil (0-20 cm) increased from 2.12 to 2.31 % between 1991 and 2005. This represents an increase of 5 700 kg C/ha (approx. 400 kg/year). Crop rotation: Ley I (L), Ley II, Ley III, Winter wheat (WW), Spring crop with insowing (Spr.cr + ins).



## THE FOOD WE EAT AND ITS IMPACTS ON THE ENVIRONMENT AND CLIMATE CHANGE

A common argument against organic agriculture is that yields are lower, so that organic production requires more land. To fill out the picture, we have to weigh in the environmental impacts per consumer: per capita nitrogen leakage to the environment is, for example, nearly two-thirds less when the consumer eats only food from ERA farms.

### Food from ERA farms

Conversion of all agriculture to the system of production established on the 48 BERAS farms would afford far-reaching benefits to both the health of the Baltic Sea and global climate change. To look on isolated products without attention from which system give not the information we need for a sustainable consumption. A fair assessment requires that we compare agriculture as practiced today with Ecological Recycling Agriculture from the point of view of our food choices, that is, what we eat, from which systems it comes from (local vs. non-local) and how it is grown. The system of production, plus the kinds of food produced add up to the overall environmental impact.<sup>51</sup>

In 2004 fifteen families who chose organic diets in and around Järna, Sweden, were interviewed about their food consumption. A similar study was carried out in Juva, Finland, and the results of both surveys were reported in the BERAS project.<sup>52</sup> On average, consumers of organic food in Järna had a more lacto-vegetarian orientation than the average family in Sweden. They ate 80 per cent less meat, and the meat they ate was primarily from ruminant animals (local lamb and beef, mainly organic). They ate somewhat more dairy products, less potatoes, but more of other roots and greens (Figure 56).



The system of production, plus the kinds of food produced add up to the overall environmental impact

<sup>51</sup> Hannula, A & Thomsson, O (2005) Consumer surveys in Juva, Finland, and Järna, Sweden, for identification of eco-local food baskets. In: Granstedt, A, Thomsson, O & Schneider, T (eds.) Environmental impacts of ecological food systems; Final report from BERAS WP2. Uppsala: Centre for Sustainable Agriculture (CUL), SLU. BERAS report; 5; Ekologiskt Lantbruk; 46. (Available at [www.jdb.se/beras/print.asp?page=32](http://www.jdb.se/beras/print.asp?page=32)).

<sup>52</sup> Granstedt, A, Seuri, P & Kuisma, M (2005) Food basket scenarios. In: Granstedt, A, Thomsson, O & Schneider, T (eds.) Environmental impacts of ecological food systems; Final report from BERAS WP2. Uppsala: Centre for Sustainable Agriculture (CUL), SLU. BERAS report; 5; Ekologiskt Lantbruk; 46.

On the basis of this study and official statistics on average annual food consumption in Sweden, four alternative scenarios for the environmental and climate consequences of diet choices were identified

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; and
4. An alternative food consumption (e.g. less and different kinds of meat), ERA farms, and local (small-scale) food processing and transports.

Figures 57, 58a and 58b summarize the findings.

### The impact on the sea

As we have seen in the foregoing, Ecological Recycling Agriculture can, under Swedish conditions, lead to a 75 per cent reduction of nitrogen leakage from cropland, compared to the average conventionally cultivated farm with its specialization in either crop or intensive animal production. Phosphorus losses, too, are reduced since there are no phosphorus surpluses on ERA farms in contrast to farms that produce too much manure.

Figure 56. Mean consumption of basic food categories kg per capita Swedish Conventional compared with Järna survey ecological consumption 15 families documented in BERAS-project 2005.

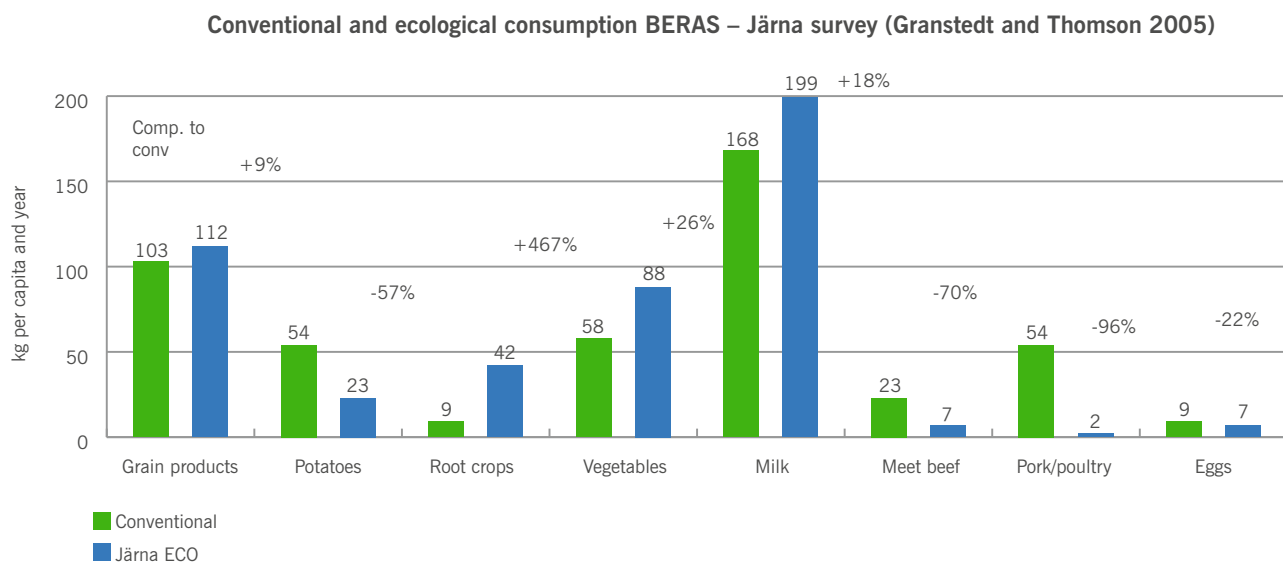
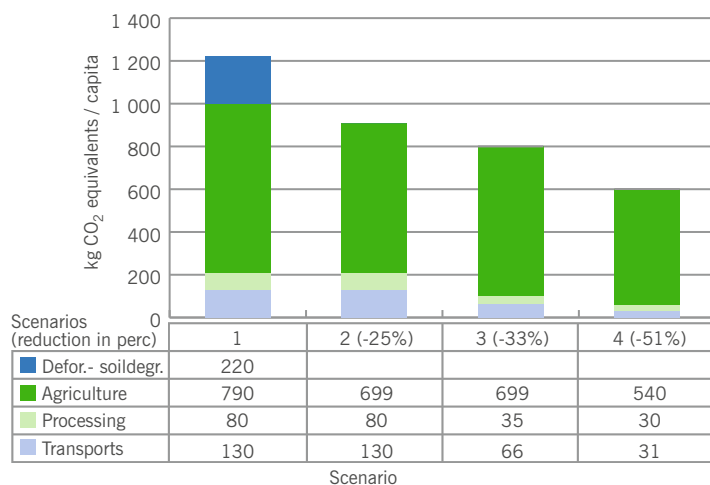




Figure 57. Nitrogen surpluses per capita at farm level and surpluses at field level, assuming present conventional consumption patterns (Scenario 1); consumption of food products from BERAS farms (Scenario 2); consumption of primarily locally produced food from BERAS farms (Scenario 3); and primarily lacto-vegetarian consumption from BERAS farms (Scenario 4).

A common argument against organic agriculture is that yields are lower, so that organic production therefore requires more land. But, to fill out the picture, it is important to weigh in the environmental impacts per consumer. As shown in Figure 57, per capita nitrogen leakage to the environment is, for example, nearly two-thirds less when the consumer eats only food from ERA farms, compared to food from modern, conventionally managed farms. The results are based on an evaluation of real farm practices for three years, where harvests were somewhat lower than conventional farms, and meat production required more pasturage since animals are fed a greater share of grass and clover instead of grain and imported soya.

Figure 58a. Annual per capita emissions of greenhouse gases (CO<sub>2</sub> equivalents) from Swedish agriculture, food processing and transports, assuming present conventional consumption patterns (Scenario 1); consumption of food products from BERAS farms (Scenario 2); consumption of primarily locally produced food from BERAS farms (Scenario 3); and primarily lacto-vegetarian consumption from BERAS farms (Scenario 4).



Notes

**Defor. soil degr.:** Emissions due to deforestation and soil degradation in order to produce palm oil (Malaysia) and beef (Brazil) for Swedish food production and consumption (SNV Report 5903, 2010). Additional indirect emissions of greenhouse gases resulting from the production of soybeans, another ingredient in conventional fodder, are not included here.

**Agriculture:** Other climate impacts from agriculture, including animals' emissions of methane, etc.

**Processing:** Emissions of greenhouse gases in secondary production (slaughter, milling, bakery, dairy)

**Transports:** Miscellaneous transportation from farm to shop.

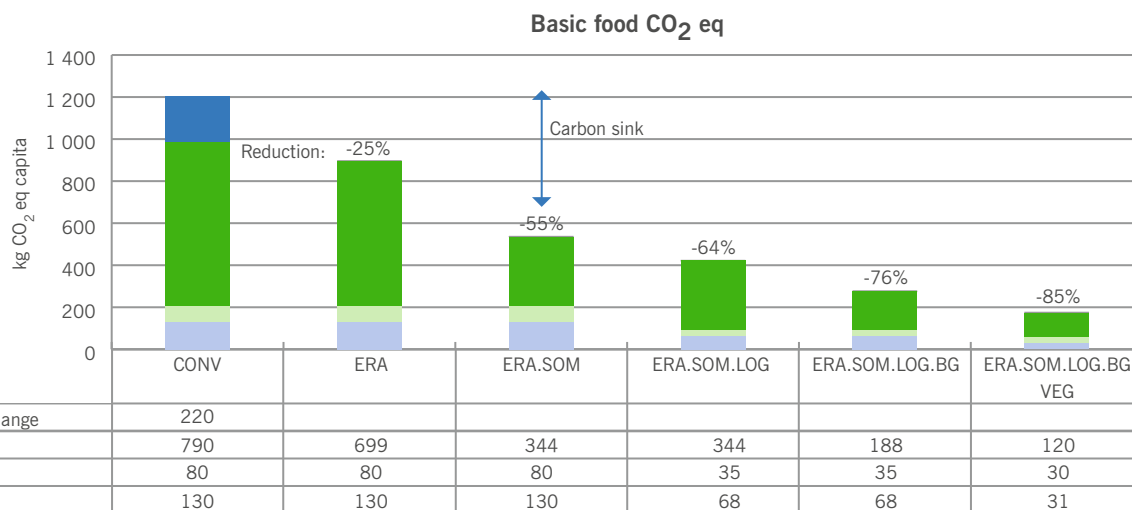


Figure 58b. Steps toward climate-friendlier diets (scenarios based on the findings of a study of household food preferences in Järna conducted in the framework of the BERAS project). Food exclusively from Ecological Recycling farms: -25%. Plus measures to increase humus in the soil (a 'carbon sink'): -55%. Plus choosing locally produced and processed foods: -64%. Plus biogas production on the farm: -75%. Plus eating less meat (the mean diet in Järna): -85%. Note that it is more than a question of choosing certain food items; it is a question of systemic changes, both in the way we farm and in our personal lifestyles. For example: less meat in our diets, but a greater share of meat produced by grazing (rough fodder) leads to less deforestation in, for example, Brazil, while it increases the mulch content of farmland here at home.

Less meat consumption and proportionally less meat production would, according to Scenario 4, reduce nutrient losses even more. The calculations in Scenario 4, with 80 per cent less meat consumption and more consumption of vegetables, indicate that nitrogen leakage might be reduced by 80 per cent.

The calculations in Scenarios 1 and 2 are based on current average consumption of meat, dairy products and vegetable foods. In Scenario 2 agricultural products are assumed to come exclusively from ERA farms. The organic meat in the BERAS food basket consists of more beef and less meat from single-stomached animals, such as pigs and poultry, compared to current patterns of consumption. Furthermore, some of the food and animal feed is presumed to be imported. A greater share of locally grown and processed food does not affect the leakage from agriculture, but makes it possible to recycle more food waste locally.

Implementation of Scenarios 2 and 3 on a national scale would require a considerable increase in the area under cultivation from 3.2 million hectares (including an 'imports acreage' of approximately 0.6 million hectares) to 4.7 million hectares, some of which might consist of more or less permanent pasturage. In this scenario, the cultivated area would be greater than the total arable land in Sweden in the early 1900s. Much arable land in the Baltic Sea region lies idle today – in Latvia and Lithuania, for example.

Most desirable in a global perspective is Scenario 4. A 80-per cent reduction of meat consumption reduces the area required to feed a person by 40 per cent, compared to the present requirement (0.24 ha instead of 0.4 ha); at the same time, it makes it possible for agriculture to rely entirely on locally produced and renewable resources, with minor negative environmental impacts.

More details are presented in the BERAS report, Environmental Impacts of Ecological Food Systems (see note 40).

### Climate impact

An ERA farm saves all the fossil energy that is used to produce the synthetic fertilizers used in conventional agriculture. In central Sweden, cultivated clover fixes 200 kg of nitrogen per hectare; it takes 200 liters of oil to fix 200 kg of nitrogen from the atmosphere. In addition, the production of synthetic fertilizer in most factories today releases nitrous oxide, a powerful climate altering agent, to the atmosphere. Per capita emissions of greenhouse gases in Scenario 2 are 25 per cent lower, given consumption of products from BERAS farms, which are self-sufficient in fodder and do not entail the emissions associated with feed imports. The climate impacts of deforestation to clear land for soya and other crops has been taken into account here. Per capita emissions are 33 per cent lower when all the food consumed is locally produced (Scenario 3), and 50 per cent lower when meat from single-stomached animals is excluded from the diet, as well (Scenario 4).

### On Farm Biogas production with solid manure in organic farming




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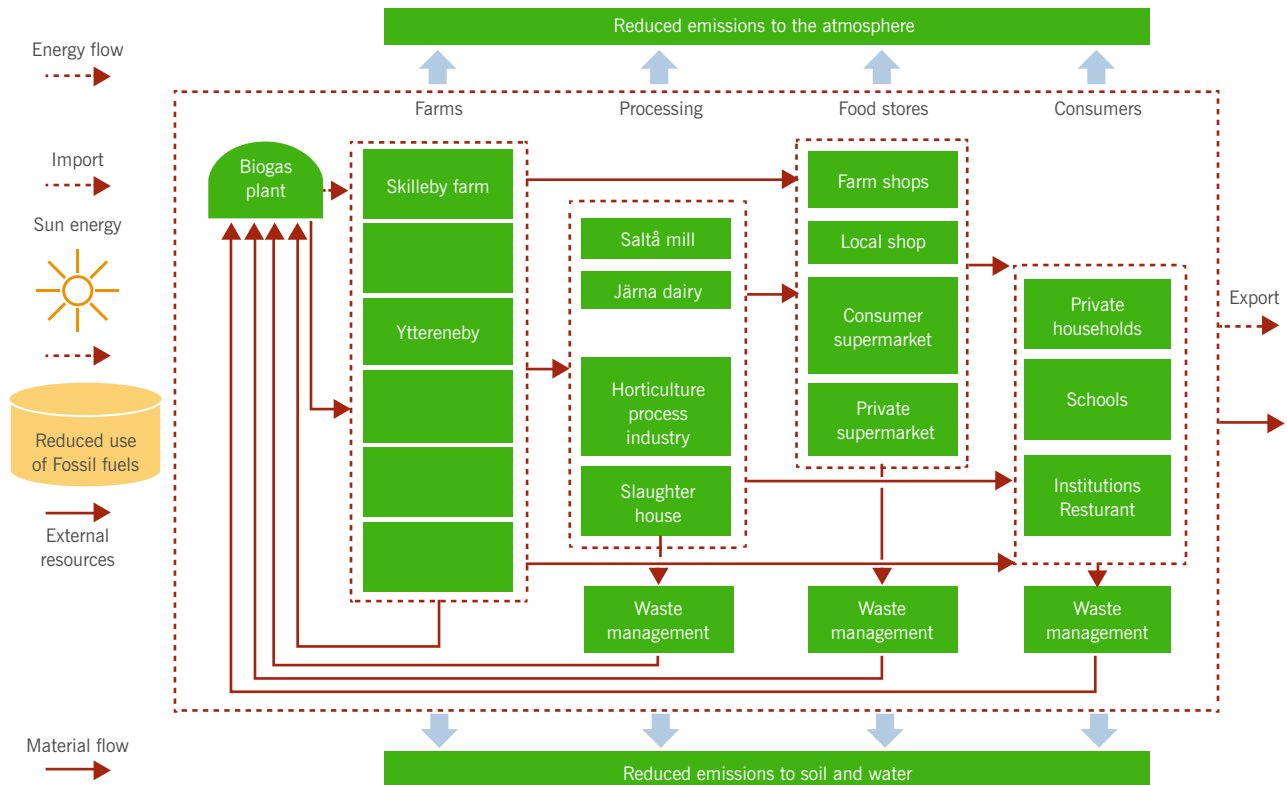
Figure 59a. The performance of a two-step farm-scale biogas plant, established by the Biodynamic Research Institute at Skilleby-Yttereneby Farm, has been evaluated during the period 2004-2010. (Granstedt, A (2012) On farm biogas production, [www.jdb.se/sbfi](http://www.jdb.se/sbfi)). The plant produces biogas primarily from the farm's production of manure. It is unique in that it operates with solid material, which makes it possible after gas extraction to compost the manure in accordance with biodynamic practices. Composted manure has been shown to improve soil fertility. A detailed technical description and evaluation of the biogas plant is available: Schäfer, W.; Lehto, M. & Teye, F. (2006). Dry anaerobic digestion of organic residues on-farm - a feasibility study. Agrifood Research Reports 77, Vihti, Finland, Retrieved from <http://orgprints.org/6590/>

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## The food we eat

Figure 59b. Given a complement of local, quality-controlled food waste, the plant can produce the amount of renewable energy needed to satisfy the farm's fuel needs so that, provided the other measures outlined here are taken, the farm can attain climate neutrality. In the future, it will be possible for several farms to co-produce energy. Fermentation may be done on the respective farms, whereas production of the gas to fuel vehicles can be undertaken collectively with cooperation between farms. Such an operation enhances the recirculation of the plant nutrient capital in the local farming community, produces renewable energy, and palpably reduces losses of damaging waste to both air and water. An evaluation of the system found that nitrogenous gas emissions were cut by roughly 50 %, while nitrogen efficiency increased substantially, as indicated by higher yields.

Farming systems that rely on biological nitrogen fixation also improve the humus content of the soil in contrast to this conventional farming systems which are driven without clover grass in the crop rotation. Humus formation works as a 'carbon sink', more carbon is bounded in the formation of increasing amount of soil organic matter than is given off through decomposition of organic matter. The annual amount of bound CO<sub>2</sub> in the example is estimated to amount to 400 kg carbon (about 1500 kg CO<sub>2</sub> eq per hectare). Farms can also compensate for the energy used to fuel tractors and machinery by producing biogas from manure. Such production is tested on Skilleby-Yttereneby Experimental Farm in Järna, for example. If we combine the realization of the climate neutral farming system and a lifestyle with near no use of meat from chicken and pigs an even reduce use of ruminant meat according the example given in figure 56 it should be possible to reduce the green house emissions from the basic food consumption with more than 80 % which is necessary for all sector in perspective of the global warming (Figure 8). The different steps in changing both agriculture and food consumption is presented in figure 58 b.





Even in the context of a self-sufficient farm smaller amounts of pigs or chickens are well motivated, as both play a valuable role as 'scavengers' and processors of the spill and by-products from the food production and be an imported part integrated the farm and food system. But to big scale will not be realistic in a near future to survey on local and renewable resources.

### Impact on biodiversity

Comparative studies have found greater biodiversity on ecological farms.<sup>53</sup> Up to one ton of earthworms per hectare have been found under conditions obtaining in central Sweden. That is double the volume that has been measured on some conventionally cultivated farms. These fertility-enhancing organisms are not very tolerant of pesticides, and their living conditions are impaired in systems with no organic fertilizers. Mycorrhiza fungi, vital as suppliers of phosphorus to root systems, suffer when fungicides are applied. Pesticides also kill beneficial insects like ladybug beetles and their larvae. We find ourselves at a fork in the road, where continued use of chemicals in agriculture disrupts essential ecological functions in the living soil and vegetation, so that dependence on chemical compounds increases, with negative consequences for surrounding ecosystems, as well.



<sup>53</sup> Ahnström, J (2002) Ekologiskt lantbruk och biologisk mångfald: en litteraturomgång [Ecological agriculture and biodiversity: a survey of the literature]. Centre for Sustainable Agriculture (CUL), SLU.

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Figure 60. Restored wetlands like those at Skilleby (pictured here) have the dual purpose of further reducing nitrogen and phosphorus losses and enhancing biodiversity. To the right, the climate monitoring station connecting to the monitoring station that records climate data, collecting water-proofs and outflow to the pond from a drainage area of 22 ha on the farm.

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The BERAS farms are good examples of how farming in the region can be successful and maintain ecological balance, with no use of chemical inputs and low leakage of nutrients to the environment

## TAKING THE STEP

Perhaps the farm has already invested in a larger pig stall or a barn for 200 cows. With luck there may be a grain-producing farm nearby to collaborate with: The grain-grower buys manure from the animal farm, and the animal-farmer buys feed. Together, they become an ecological team.

### Wherever the land is arable

The 48 farms that participated in the BERAS Project 2003 – 2006 and the additional ERA farms in BERAS-implementation project show that it is possible to operate an Ecological Recycling farm under the most varying conditions in the Baltic Sea region, from the harsh climate of the far North and meager sandy soils in Poland to the prodigiously fertile loam of southernmost Sweden and Denmark. The soil is managed differently and different crops are raised, depending on environmental conditions, the size of the farm, existing buildings and installations, available capital and prevailing market conditions, but also to a large degree according to the intentions and orientation of the farmer. Common to all these farms is a commitment to adapt to the fundamental rules of ecological balance and to minimize ecological impacts and the use of resources.

The BERAS farms are good examples of how farming in the region can be successful and maintain ecological balance, with no use of chemical inputs and low leakage of nutrients to the environment. Crucial to sustainability in the longer term is that the farm also gives a satisfactory economic yield – that it affords a good return on the labor put into it and covers the costs of operations and financing.<sup>54</sup>

### Economic possibilities ...

Farms that have not converted to extreme specialization, with all the investments such conversion entails, can convert to Ecological Recycling Agriculture without any greater economic sacrifice. Together, the premium on organic products offered on the market and the conversion support offered by the EU mean that many ERA farms show at least as good economic results as conventional farms. The economic analyses performed in the BERAS project confirm this. In political economic terms, ecological production, coupled with a greater share of sales on the local market and local processing, have boosted local economies, providing jobs and enhancing the quality of life.<sup>55</sup>

### ... and stumbling blocks

What can complicate a conversion, despite a strong desire to convert, is if the farm has made major investments in a form of production that is not

<sup>54</sup> Reeder, H (2004) Possibilities for and economic consequences of switching to local Ecological Recycling Agriculture. *Ekologiskt Lantbruk*; 43. (Swedish University of Agricultural Sciences, SLU)

<sup>55</sup> Nousinen, M et al. (2009) Are alternative food systems socially sustainable? A case study from Finland. *Journal of Sustainable Agriculture* 33:566-594. (BERAS Project)

compatible with the ecological principle of minimizing the use of resources, through avoiding polluting nutrient losses and climate-altering gases by closing resource cycles, relying on renewable energy sources and maintaining biodiversity. Major investments in massive stalls designed, for example, for two thousand pigs or a 'barn' for 200 milk-cows may have required credits, which may take a lifetime to pay back. Credit payments and interest have to be paid out of operations that use the costly installations.

Investments like this can mean continued dependence on large-scale animal production, largely based on purchased feed, which, as we have seen, gives rise to leakage of nutrients from the farm. How the problem can be solved varies from case to case. With luck, there may be a grain-producing farm nearby with which the animal farm can join to form what might be called an ecological partnership, whereby the grain-grower purchases manure from the animal farm, and in return the intensive dairy farmer buys feed. Together, the farms can form an ecologically sound system, albeit some adjustments may be necessary. Combinations like this may be a solution for many, and some good examples do exist.

Solutions are harder to find when the distance between complementary farms is too great. As noted earlier, there are whole regions that have specialized in grain production without animals, and other regions with entirely too many animals. Farms specializing in plant production generally find it easier to reintroduce animal production based on coarse fodder and grazing, although there may be costs for buildings. There are good examples of such conversions in flatlands where grain-production took over in the 1960s and 1970s. It is far more difficult for an animal farm in an animal-producing region to find a matching 'eco-partner'.

According to conventional norms, an animal farm is allowed to contract to spread manure in amounts corresponding to up to 1.5 animal units per hectare. Conversion to well-functioning ERA production that is self-sufficient in feed will require a major reduction in the number of animals. Here, too, there are examples of successful conversions, where past 'steps in the wrong direction' today house ecologically sound economic activity. On Solmarka Farm in southeastern Sweden, for example, a large pig stall has been rebuilt to house a Demeter-certified bakery and a farm shop. Farms in areas suitable for the purpose have converted to producing organic vegetables, using existing structures to sort, process and package vegetables for the market and to store roots.

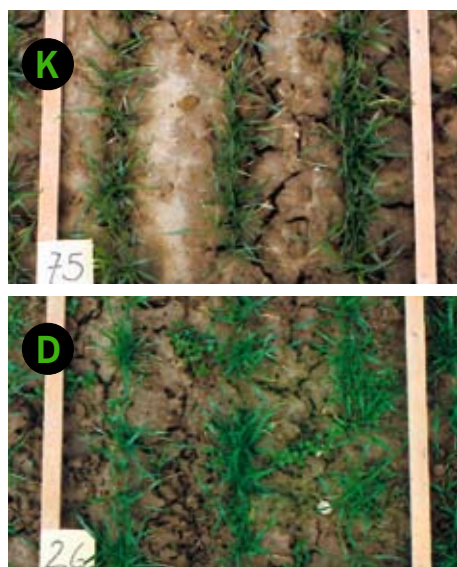
### Yields and profitability

As we have seen, between 1800 and 1950 farming practices in Sweden obeyed ecological principles. (The period was a bit earlier in Denmark and even earlier in the rest of Europe, and somewhat later in Finland.) Thus,



What can complicate a conversion, despite a strong desire to convert, is if the farm has made major investments in a form of production that is not compatible with the ecological principle of minimizing the use of resources, through avoiding polluting nutrient losses and climate-altering gases by closing resource cycles, relying on renewable energy sources and maintaining biodiversity

Figures 61a and b. Autumn wheat in the long-term Swiss field trials, known as the DOK experiment, which compared conventionally raised (K, upper photograph) with biodynamically raised (D, lower) wheat. The difference in the soil structure, with mulch content of 3.65% in soil under a biodynamic regime, compared to 2.8% mulch in soil treated with synthetic mineral fertilizer only, is clearly visible after twenty years' time. There are more signs of life in the former: viz., worm excrement, visible aggregates, pores and soil structure. Source: Mäder et al. (2002).

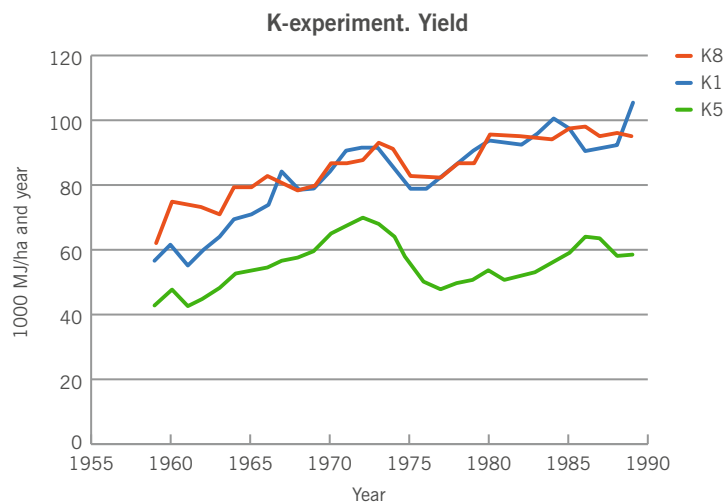


Figur 61c. The trend in yields expressed in energy units (MJ/ha) from 1959 to 1989 for three treatments: the biodynamically fertilized plot K1, the synthetically fertilized K8, and the unfertilized K5. The plant nutrition in treatment K5 consisted of solely the nutrients provided by including ley in the four-year crop rotation and the nitrogen-fixation that takes place in cultivated ley. Source: Kjellenberg, L & Granstedt, A (2005) *The K-trials. A 33-year study of the connections between manuring, soils and crops. Biodynamic Research Institute, Järna Sweden. The full report may be downloaded at <http://www.jdb.se/sbfi/publ/k-trial.pdf>.*

the notion that it was thanks to the use of chemicals in agriculture that growing populations could be fed is a wrong information. Industrialization of agriculture, with specialization and separation of animal from vegetable production came only after the world war. Despite a growing dependence on synthetic fertilizer and chemical pesticides overall as a consequence of this industrialization, a small minority of farmers chose another route and laid the foundation for what we today know as ecological or organic agriculture. The rise in productivity after 1950 occurred on conventionally managed and ecological farms alike and thus occurred whether or not chemical inputs were used. The new technology that made higher yields possible on conventional farms was used by ecological farmers, as well.

This is confirmed in the above-mentioned long-term field trials in Järna that started in 1958 and continued until 1990. The original purpose of the trial was to test different applications of fertilizer for comparisons of product quality. It also afforded an opportunity to follow the development of soil fertility and the trend in yields. Yields increased in both conventional and biodynamic-organic treatments (Figure 58). The four-year crop rotation consisted of ley, potatoes, beets and summer wheat with insowing. Eight different treatments were included; K8 corresponded to conventional norms, with 100 kg nitrogen per hectare in the case of summer wheat. Treatment K5 was without fertilizer.

Treatment K1, a fully biodynamically cultivated crop, was fertilized with manure, the amount of manure being based on fodder from 75 % of the production. After the first ten years, treatment K1 had reached the same level of productivity (expressed here as MJ per hectare and year) as the conventionally fertilized treatment, K8, and K1 harvests then continued to rise corresponding to those of K8. Post-harvest characteristics like storage properties (sustained freshness, resistance to rot, etc.), protein composition and vitamin content were rated higher in the organically cultivated crops. The reason why yields increased even without the



more soluble synthetic fertilizers has to do with greater soil fertility in the form of biological activity in the soil, the formation of aggregates and the previously mentioned increase in the thickness of the humus layer that could be documented in the organic treatments and compared with conditions in conventionally fertilized plots.<sup>56</sup>

The results of this so-called K study were subsequently verified in field trials conducted simultaneously at the predecessor to the Swedish University of Agricultural Sciences at Ultuna and at the Nordic Research Council in Järna for six and nine years, respectively, and with four replications at both sites under the supervision of Bo Pettersson.<sup>57</sup> The findings are reported in the first Swedish doctoral dissertation in the field of ecological agronomy (Pettersson 1982; Dlouhy, 1981).<sup>58</sup> Summer wheat yields were 12 (Ultuna) and 8 per cent (Järna) lower than conventional treatments, whereas ley yields were the same in both systems. The superior soil fertility characteristics found in organic plots – especially the biodynamic plots – compared to conventionally cultivated plots has since been documented in many longitudinal field trials in Europe. These results have been published in the respected journal, *Science*.<sup>59</sup> Continued Swedish study of soil fertility shows consonant results.<sup>60</sup>

The DOK trials, a longitudinal study in Switzerland, found 11-14 per cent lower yields in biodynamic and organic cultivation compared to conventional growing. At farm level the differences can be greater than the averages reported in foreign and Swedish field trials. Generally speaking, it takes some time after conversion before the soil develops its superior fertility in the form of more humus in the topsoil and subsoil, a greater number of earthworms and more biological activity in the soil – as has been documented for biodynamic and organic cultivation. How long it takes depends on prevailing conditions and how the land was used previously.

On good soil the harvests of conventionally cultivated crops may for a time be greater than ecologically cultivated crops and what might be called traditional ‘environmentally adapted’ conventional cultivation through a liberal application of chemical substances, i.e., controlled application of synthetic fertilizer (often several times during the growing season) and chemical pesticides according to a plan, called ‘programmed cultivation’. The harvests that can be attained in these cases are far greater than can be achieved with natural inputs: 10 tons of wheat per hectare in southernmost Sweden and nearly 15 tons on the Continent, i.e., 50 to 100 per cent greater yields. The density of growth and the nature of the plant cells given high doses of fertilizer mean that the plants need chemical protection against fungi and growth-regulating agents from the start to keep the plants upright. Furthermore, they require more protection against insects (insecticides). The only limits to what may be used are the prohibitions set out in law.



The superior soil fertility characteristics found in organic plots – especially the biodynamic plots – compared to conventionally cultivated plots has since been documented in many longitudinal field trials in Europe. These results have been published in the respected journal, *Science*

<sup>56</sup> Pettersson, B D et al. (1992). Düngung und Bodeneigenschaften: Ergebnisse eines 32-jährigen Feldversuches in Järna, Schweden [Fertilizing and soil characteristics: findings of a 32-year field trial in Järna, Sweden]. Nordisk Forskningsring Meddelande; 34.

<sup>57</sup> Pettersson, B (1982) Konventionell och Biodynamisk odling. Jämförande försök mellan två odlingssystem [Conventional and biodynamic cultivation: empirical comparisons of two systems of cultivation]. Nordisk Forskningsring. Meddelande; 32.

<sup>58</sup> Dlouhy, J (1981) Alternativa odlingsformer – växtproduktens kvalitet vid konventionell och biodynamisk odling [Alternative forms of agriculture: Quality of products from conventional and biodynamic growing]. Uppsala: Dept. of Plant Husbandry, Swedish University of Agricultural Sciences. Report; 91.

<sup>59</sup> Mäder, P et al. Soil fertility and biodiversity in organic farming. *Science* 296:1592-1597.

<sup>60</sup> Granstedt, A & Kjellenberg, L (2008) Organic and biodynamic cultivation: A possible way of increasing humus capital, improving soil fertility and being a significant carbon sink in Nordic conditions. Modena: Second Scientific ISOFAR Conference, 18-20 June.





In the long term, chemical agriculture implies a gradual degradation of the natural conditions that in the short term made these monocultures and this input-intensive form of agriculture possible in the first place

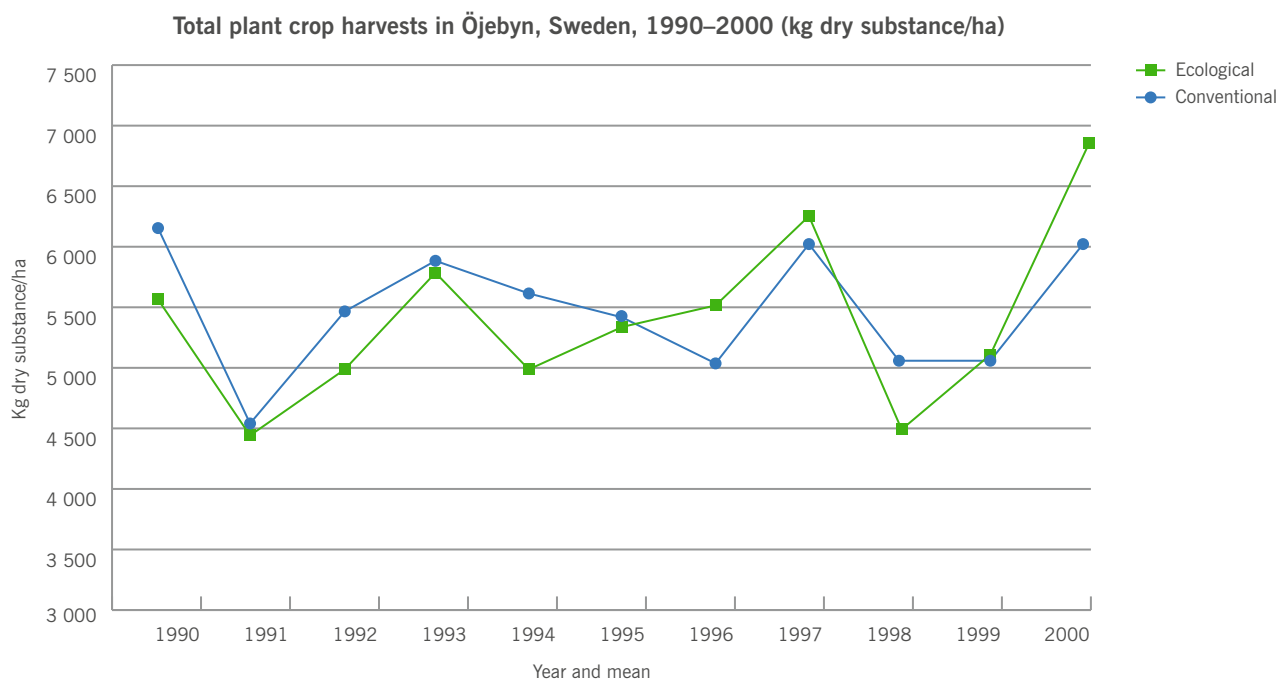
Figure 62. Harvests of all crops at Öjebyn in comparative field trials. Source: Jonsson, S (2001) *Två gårdssystem i Öjebyn – plan och utfall efter 11 år* [Two systems of production in Öjebyn – projected and actual yields after 11 years]. *Ekologiskt Lantbruk, Ultuna 13-15 november, Swedish University of Agricultural Sciences.*

### Chemical agriculture is demanding

Chemical-intensive agricultural systems require a large area for mechanized crop maintenance, irrigation and an infrastructure and economic resources that enable the farmer to fulfill the program. At the same time, this kind of agriculture is the most questionable with regard to long-term sustainability and environmental impacts, both here in Europe and in developing countries. In countries with weak laws that do not forbid the most hazardous chemicals, where knowledge of the precautions surrounding use of the chemicals may be lacking, many workers suffer injury and ill health, and levels of pesticide residues in food may be hazardous. In the long term, chemical agriculture implies a gradual degradation of the natural conditions that in the short term made these monocultures and this input-intensive form of agriculture possible in the first place. On more marginal lands, arable land has already been lost through degradation of organic matter in the soil, salinization and soil erosion. Ultimately, the availability of external resources also sets limits.

Under the conditions that prevail in northern Scandinavia, there is no difference between the yields of ecological and conventional systems. The economic result may even be better in ecological production by virtue of the absence of costs for synthetic fertilizer and pesticides. Here, natural conditions set limits even in a shorter perspective.

At SLU's Öjebyn Experimental Farm outside Umeå, Sweden, full-scale conventional and ecological methods were compared over a



ten-year period. The farm, both animal and crop production, was divided up between the two systems. Harvests in the ecological parts of the farm were somewhat higher than in the conventional parts; animal production (meat and milk) was roughly equal; while the economic result (not counting any premiums for organic cultivation or environmental compensation from the EU) for the ecological part was better, thanks to lower input costs (Figure 62).

For farmers in areas of marginally arable land around the world ecological farming practices afford a way to improve productivity to feed local populations. On very good agricultural land, where the so-called 'green revolution' took place, agricultural practices are exploiting finite resources in a short-sighted and unsustainable way. Even here long-term sustainability requires a conversion to ecological methods.

According to Roland Bunch, who has worked for decades with farmers in Africa, Latin America and Asia, ecological factors like soil fertility and access to water are the main factors standing in the way of good nutrition and health.<sup>61</sup> What the poor farmers in these areas need are innovations that make it possible to overcome these hindrances at low cost and build up their capacity to achieve better and more stable harvests. Furthermore, the methods have to be flexible enough to be used in many different ecological settings.

Biodiversity, companion crop cultivation, crops and plants that fix atmospheric nitrogen and closed cycles of plant nutrients, combined with techniques to prevent soil erosion and increase the humus content of the soil (which saves water) are a good fundament on which to build food security in currently famine-stricken areas. According to statistics from the UN Food and Agriculture Organization, such areas are home to more than one billion people today.

### Ecological recycling brings better nutrition

In connection with the BERAS project's evaluation of the importance of recycling to economizing with resources and protecting the environment, studies also focus on soil fertility and the nutrition of harvested crops. The results of previous long-term field trials show that many years of continuous grain production lead to depletion of the minerals in the soil, which also affects the nutritional value of the grain produced on specialized grain-producing farms. Comparative studies at farm level and more recent experiments have found that greater quantities of trace elements are present in ecologically produced grain than in the grain conventionally produced on specialized farms that have no animals. Without recycling, important nutrients are depleted in the soil and product alike.



The results of previous long-term field trials show that many years of continuous grain production lead to depletion of the minerals in the soil, which also affects the nutritional value of the grain produced on specialized grain-producing farms

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*The basic elements needed to secure food supplies in regions of famine are: preservation of biodiversity, companion cropping, crops and vegetation with the capability to fix atmospheric nitrogen, and recycling of plant nutrients with no losses. In addition, measures must be taken to combat soil erosion and to increase the mulch content in the soil, which in turn improves water economy. According to statistics from the UN Food and Agriculture Organization (FAO), roughly one billion people live in areas that are subject to famine. Smallholding farmers in critical regions can double their harvests within ten years if they convert to ecological farming methods, according to a comprehensive review of research published by the UN Human Rights Council, Agroecology and the Right to Food (2011) [www.srfood.org](http://www.srfood.org).*

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<sup>61</sup> Bunch, R (2002) Increasing productivity through agro-ecological approaches in Central America: experiences from hillside agriculture; Tiffen, M & Bunch, R (2002) Can a more ecological agriculture feed a growing population. In: Uphoff, N. (Ed.) *Agroecological Innovations*. Earthscan, London.



Map showing the location of partners and information centers in the BERAS-implementation project, 2010-2013. BERAS-implementation is financed in part by a grant from the European Union.



Drainage area of the Baltic Sea and West Sea which include whole Sweden (Sverige), Estonia (Estland), Latvia (Lettland), Lithuania (Litauen) and Poland and parts of Russia (Ryssland), Belarus (Vitryssland), Germany (Tyskland), Denmark (Danmark), and Norway (Norge). There are more farmland and more people living in south and south east compared with the north. The red dots inform about amount of inhabitants in the main cities: 3 000 000, 1 000 000, 300 000, 100 000 respectively. Besides cities are the many people living in the countryside. Yellow color is farmland .

**“ When you don’t use chemical fertilizer and pesticides, you see immediately if something’s gone wrong. A patch in the field where plants aren’t doing so well signals that there may be a problem in the drainage system or that the soil has been compacted there. When you use chemicals, the plants aren’t as dependent on biological processes in the soil, and problems like these might not be noticed.”**

*Staffan Aresund, Nibble Farm, Järna*

## THE OUTCOMES AT BERAS FARMS

A total of 48 ecological farms in the eight EU Member States bordering on the Baltic Sea took part in the project, Baltic Ecological Recycling Agriculture and Society, BERAS, between 2003 and 2006. They opened their doors to evaluation and analysis of their management of plant nutrients and energy use, the results of which are reported in this book. The farms show how farming in the whole of the Baltic Sea region might be done in the future: farming based on local, renewable resources that can restore the Baltic Sea to health, reduce impacts from agriculture on the climate, stop the spread of toxic chemicals in the environment and promote rural development through more jobs, a higher degree of self-sufficiency and more secondary agriculture-related industry.

The farms also serve as models in the continuation of the BERAS project, ‘BERAS Implementation’, that seeks to identify best practices for the conversion process from conventional farming to Ecological Recycling Agriculture. The following pages offer thumbnail portraits of a few of the BERAS farms.

All the farmers were asked the following questions:

- 1. How did it all start? What prompted the change over to ecological methods?**
- 2. How is the farm doing today, some years after the BERAS evaluations?**
- 3. What are your plans for the future?**
- 4. What public policy measures would help you most to reach your goals?**

### Nibble Farm and Garden Farm

Farmer: Staffan Aresund

Location: Järna, County of Stockholm



Figure 63. Nibble Farm is one of the Ecological Recycling farms in the BERAS project. Today, there is an educational program in Natural Resource Use attached to the farm, where students learn how to manage a medium-sized farm according to ecological principles.



## SWEDEN

### NIBBLE FARM AND GARDEN FARM

The farm, which consists of cropland, pasturage and forest, lies in a coastal plain, with direct drainage to the Baltic Sea. It borders to the south on an area of moraine, which is forested; to the west lies the Järna plains. The entire farm has been in ecological and biodynamic production since the 1960s.

#### Area and soil characteristics:

The farm comprises 86 ha cropland (incl. 18 ha used for grazing), 7 ha natural pasturage and access to 15 ha fodder area in nearby Hölö.

The soil is moderately mulchy medium to heavy clay, having a good potassium status, low phosphorus content and a pH of 6.3.

#### Line of production:

The principal activity is dairy production based on home-grown fodder, combined with cereal crops on 14 ha. For a few years, the farm also grew potatoes and root vegetables. The farm employs one person besides Staffan. Nibble delivers its milk to Nibble Dairy, also located on the farm and producing sweet and cultured milk, yoghurt and a variety of cheeses.

#### Stock:

42 dairy cows (SRB), 35 young cattle, one bull, two horses, ten mother sheep and a flock of ewes.

The cows are kept tied up in a long stall cowshed.

Nibble was one of the ERA farms in the BERAS project that had a nitrogen surplus that was less than the average for the twelve Swedish prototype farms (Figure 60).

#### Crops:

*A five-year crop rotation with an emphasis on ley and cereals.*

*Outlying pasturage is renewed, as necessary.*

- *Summer wheat with insowing*
- *Ley 1*
- *Ley 2*
- *Ley 3*
- *Winter grain (at present a winter oil crop, trial)*

### Production levels

Milk production totals about 7 500 kg EMC/yr

The oat yield is about 3 000 kg/ha, summer wheat 3 500 kg/ha, winter wheat 4 500 kg/ha, Grass/legume ley 3 000-5 000kg dm/ha and year

### Self-sufficient in fodder and fertilizer

The animal density on the farm is 0.7 animal units (AU)/ha, which is optimal for achieving a high degree of self-sufficiency in fodder and fertilizer.

### Manure management

The solid fertilizer system is partly deep litter. All manure is composted before being applied to fall grains. Twenty tons of manure is provided to neighboring Nibble Garden Farm each year.

### Sales

All milk is sold to Järna Dairy, located on the farm.

Whey is recycled on the farm.

All the cereal that is not used to feed the farm's animals is sold to Saltå Kvarn, a mill and bakery outside Järna.

Bull calves are sold to beef producers.

Other animals are sold for slaughter to Närkes Slakteri.

### Economy

Eighty per cent of the farm's income comes from milk sales.

The profitability of milk production is most affected by the volume and price of purchased energy-rich feed/concentrate and the price of milk.

Organic whole seed fodder SEK 4.50/kg, conventional milk price SEK 3.44/l, organic milk SEK 4.57/l and Demeter-certified milk to Järna Dairy SEK 4.85/l.

### Future prospects

A program of cross-breeding of the farm's animals with Fleckvieh in order to enhance their metabolism of home-grown rough fodder is in progress.

Nibble Farm was one of the ERA farms in the BERAS project. It had a nitrogen surplus that was below the average for the twelve Swedish ERA farms in the project. The nitrogen surplus for the period of the study, 2002–2004, was 28 kg N/ha and year. The phosphorus balance was negative – 1 kg P/ha and year, which implies minor losses of phosphorus to the environment.



Figure 64. Nibble Farm, 2011.





The bread grain production is about 20 per cent under the average for farms in the area. Calculations show that about 15 per cent of the income a conventionally operated farm generates goes to the purchase of synthetic fertilizer and pesticides. That means that the greater part of the gap between Nibble's yield and conventional farms in the region is filled by the lower costs of inputs in ecological farming.

Staffan says he is always looking to make improvements – to improve operations with the help of what he calls “the farmer's eye”. When you don't use chemical fertilizer and pesticides, you see immediately if something's going wrong. A patch in the field where plants aren't doing so well signals that there may be a problem in the drainage system or that the soil has been compacted there. You don't see that kind of thing on a synthetically fertilized field, where the plants aren't as dependent on mineralization processes in the soil. Because fields are over-fertilized in conventional farming, the problem isn't visible. Staffan is also interested in testing how much clover he can include in his ley, experimenting with different varieties and sowing densities. More experimentation and development of varieties would be welcome, more generally.

It is not enough, however, to develop your knowledge of varieties and your soil. Much of a farm's economy depends on the animals. The predominant breed of Swedish cows (called SRB) is bred to produce a lot of milk with the help of concentrated feed. What is needed is breeding that makes cows better adapted to what they were originally created for: to process coarse fodder. There are cows like this in other parts of the world, in Iceland, for example, where they have never had access to local grain feed. Icelandic cows, like the Icelandic ponies, are descended from ancient breeds that the Vikings brought to the island from Scandinavia.



What is needed is breeding that makes cows better adapted to what they were originally created for: to process coarse fodder

### **Why ecological production?**

Frans Carlgren purchased the farm in 1966 with the intent of converting it to biodynamic production. He had previously farmed Torsätra, one of the very first biodynamic farms in Sweden, but it was expropriated by right of eminent domain. Nibble Farm, now owned by a foundation, was farmed successfully for many years by a tenant and served as a model of biodynamic agriculture long before ecological systems had won the widespread recognition they have today. The farm has been a dairy farm for generations, and the period that it was managed conventionally was a brief episode.

Staffan Aresund got his training in biodynamic methods in the 1970s. It was a natural choice for him from the beginning; it matched his idea of how a farm should be managed. He worked on several farms before taking over Nibble as a tenant with personal economic liability.

### **Current status?**

The farm continues on the same course as was laid out over forty years ago, but with an eye to all the improvements that can be made, given the size of the farm and other conditions. Nibble serves as a model farm, and Staffan is prepared to demonstrate and help anyone who needs his advice about how to manage a farm sustainably on these conditions for the benefit of generations to come.

### **Future plans?**

It is Staffan's hope that the farm will continue to operate as it has so far. There has been some talk of several farms in the vicinity joining together to share an even larger barn and milking facility, but Staffan is not interested. His farm offers everything he needs to thrive on local and renewable resources. Today, the farm has an additional function: it offers an educational program in Natural Resource Use, with an emphasis on ecological and biodynamic methods, under the auspices of the owner foundation. It also offers a sheltered work environment for one employee, a solution that other farms might consider. The dairy, located on the farm, is also an expression of a commitment to local, small-scale alternatives to the increasingly large-scale thinking that otherwise characterizes conventional agriculture. Prices are negotiated very locally. The farmer receives the price he needs, with an awareness that ultimately the price is paid by local consumers.

### **Policy measures?**

Staffan is more interested in managing his farm than he is in politics, but he feels that agricultural policy should be designed so that farms like Nibble can survive. For his own part, he would welcome more resources to support measures to maintain and preserve the landscape.



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Figure 65. Nibble Garden Farm & Nursery has been in operation since 1967 and offers a full range of vegetables and root vegetables. The shop also offers a range of staples and other food items, most of which are locally or regionally produced according to ecological or biodynamic principles.

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### Nibble Garden Farm & Nursery

The Garden Farm occupies about two hectares adjacent to Nibble farm, which is about 2.5 per cent of the farm's acreage. Since the 1970s, its shop is well-known for the quality of its plants, vegetables and root vegetables, freshly harvested in the summer months. The Garden Farm is managed as a separate enterprise, but lives in symbiosis with Nibble Farm, which produces the fertilizer it uses. Despite its small size, the Garden Farm employs more people on a year-round basis than the farm does, and the economic turnover is roughly equal to that of Nibble.

Horticultural production is a feature of three other BERAS farms, as well. In addition, a couple of the Swedish BERAS farms raise potatoes and root vegetables as integral parts of their crop rotation. The examples also show how Ecological Recycling farms can supply a full range of garden products.



Photo Artur Granstedt



## FINLAND

### PARGAS FARM

The Pargas farm is located on the southwesternmost corner of Finland, outside the town of Ekenäs/Tammisaari (see map). The soil consists of redistributed (secondary sediment) clay soils with great topographical variation: light clays on the hilltops and peaty (mulch-rich) mud clays in the hollows. The herds feed on fodder that is produced on 52 hectares of the farm's acreage. The remaining acreage is devoted to crops for the market.

Like eastern central Sweden (roughly 58°30' – 60°30' N, 15-18° E), the area is prone to dry periods in the Spring. Some years, a severe Spring drought will impair the ley harvest. In wet years, some of the low-lying fields may, on the other hand, become waterlogged.

The crop rotation on Pargas is two years of ley, followed by two years of grain. The yield is less than on corresponding BERAS farms in Sweden. Productivity may be improved through a greater share of legumes in the ley, also in combination with other nitrogen-fixing crops, like peas and beans. Calculations of the nutrient balance at Pargas for three years indicate that losses of nitrogen to the soil are 70 per cent lower than the average for Finnish agriculture. Losses of phosphorus are significantly lower; the balances were negative.

Mattias Weckström recently took over management of the farm from his parents. He has installed a new dung plate and a new barn on an open plan that allows cows to come and go as they please. The acreage on a neighboring farm, Norreby – it, too ecologically operated – would allow Mattias to increase the number of animals on Pargas, but the number is still limited to what Pargas' acreage in ley can support. Only a small supplement of grain feed is added. Most of the grain harvest is sold on the market. Mattias has also recently acquired a lease on a third farm.

#### Pargas Farm

**Farmer: Mattias Weckström**

**Location: outside Ekenäs/Tammisaari**

**Area: 68 ha**

**Animals: 18 mother cows,  
20 young bulls, calves**

Photo Artur Granstedt



Figure 66. Growing conditions on the Pargas farm are much like conditions in eastern mid-Sweden, with redistributed clay soils and dry periods in late Spring.

### Why ecological production?

Pargas made the conversion to ecological methods in 1990. The main motive was the desire to maintain the fertility of the soil in the longer term. Like many other farms in southwestern Finland, Pargas sold off its dairy cows and concentrated on grain production in 1960, in accordance with the recommendations of the time. A second reason to convert was the farmer's dislike of working with pesticides.

### Current status?

Pargas' economy is buoyed up by an extensive network for direct sale of the farm's products. Matthias retrieves his meat from the slaughterhouse and sells it to his own customers. A specialty of the farm is spelt wheat. "Open Farm Day" at Pargas in 2006 attracted 190 visitors, many of whom were the farm's regular customers. Attendance in 2009 was about 500. On Open Farm Day, visitors can tour the farm, learn about ecological methods, visit the farm cafe and buy fresh produce and other products from a market stand. Many of Pargas' customers live in Helsinki, to which Wirve Weckström makes weekly deliveries for further distribution to customers.

### Future plans?

Mattias, like his parents, is confident about the future, but at present the key to the farm's profitability is direct sales to customers, and the fact that Pargas is fairly unique.

### Policy measures?

Some ecological farmers worry that an agricultural policy that led to 100% ecological production might pose a threat to their businesses. ("If everyone raises ecological food products, why would customers go out of their way to buy mine?") Mattias, however, sees no problem. For many of his customers, contact with the farm, its atmosphere and the family is at least as important as the fact that the products are ecologically produced. Mattias is also convinced that much of the groundwork leading to a political and policy commitment to Ecological Recycling Agriculture has already been done.

## FINLAND

### REKOLA FARM IN HÄME

#### Crops

A six-year crop rotation is used on Rekola proper, and a five-year rotation on the land that the farmer leases. The leased land is in poorer condition, so that grain is raised only two years in succession after clover-grass ley. Thus, the rotation is five years instead of six.

#### In the case of field crops the rotation is

- Clover ley
- Clover ley
- Clover ley
- Summer wheat, rye or barley
- Oats and peas
- Oats + insowing ley seed

#### In the case of garden crops:

1. Open fallow and ley seed
  2. Clover ley
  3. Chinese cabbage, leeks, celeriac or cereals
  4. Root vegetables, lettuce, onions and beans.
- Vetch and oats as intermediate crops in the Fall.

Garden crops are raised on an area of about 2 ha, chiefly on a field that has lighter soil.

The rotation is in four-year cycles. Chinese cabbage is raised in a phase planned for garden crops, but due to an infestation of *Plasmodiophora brassicae* (cabbage clubrot) other cabbage varieties (head cabbage, broccoli, rutabagas, etc.) are grown using the rotation for field crops. These crops are raised on part of the larger area of the farm that is considered most appropriate. More compost is applied to this acreage than to the rest of the cropland on the farm.

The principal factor that affects the size of the harvest on land consisting of silt is moisture conditions in the Spring. The average yield for grain has been just under 3 tons/ha. Garden vegetables can be watered with a sprinkler, so that there is less variation in the size of the harvest of garden vegetables than for grain. Weeds have cropped up around patches where the crop density is low.

#### Rekola Farm in Häme

Farmers: Joonas Rekola and Henri Murto

Location: near Tampere  
(in Häme, south-central Finland)

Area: 31 ha cropland, 118 ha forest  
(+ 5 ha of cropland on lease)

Animals: 0,5 animal units per hectare  
of cropland



Figur 67a. One of the upcoming generation, Joonas Rekola, getting acquainted with one of his Pomo cows.





67b. The younger generation, here represented by Henri Murto, is eager to continue Rekola's well-established bakery, which delivers to shops in Tampere and adjacent communities. Recently, bread using a home-grown spelt was added to the assortment.

### Animals

Rekola has many different kinds of animals, but the total number is kept within a reasonable proportion to the cultivated acreage. They are 0.5 animal units per hectare of cultivated land, and the farm fulfills the criteria to be self-sufficient in fodder and crops for the market.

The non-heated walk-in barn, built more than ten years ago, houses twelve mother cows and their calves. The cows are Limousine cross-breeds. The barn has proven to work well, provided there is enough space in the stalls so that less vigorous animals can be on their own. Straw is used as dry bed under the cows, and manure is removed once a week. The beef cattle have mainly fed on coarse fodder. The first harvest of grass is dried to make hay, and the second growth is turned into dry fodder packed in round bales. The animals are fed straw, with the bulls being given a maximum of 4 kg oats-and-peas per day.

Rekola has a scenic location on the shore of Lake Längelmävesi. The farm receives an environmental support money to maintain the traditional biotope on a point that juts into the lake. Thanks to the stipend, farmers have been able to fence the area, where sheep graze.

### Value-added products

Kalervo's wife is in charge of the biodynamic bakery. The bakery started up in 1977, and at present it offers a traditional sour rye bread, a wheat bread, a fruit bread, and müsli. The heart of the bakery is a big stone oven, which is fired with wood from the property.

The varied production and the farm's long history are paying off. The farm has a circle of loyal customers who buy a good share of what the farm produces. There is a social aspect to Rekola Farm, as well. Besides maintaining personal contact with the farm's customers, the family has organized a group of volunteers who are pleased to help out in periods when there is a lot of work to be done. Open-house parties at Midsummer and after the harvest strengthen the bonds between the farm, their customers and the local community.

### **The plant nutrient balance**

Rekola Farm was one of four Ecological Recycling farms that participated in the BERAS project in Finland. Plant nutrient balances were calculated for three years and the balance was followed up again in 2007. Nitrogen surpluses at Rekola are about 37 kg N per hectare and year, while there is a deficit of 1 kg per hectare for phosphorus. This is a little less nitrogen and phosphorus per ha than the average for the other Finnish ERA farms, but quite in line with the average for Swedish ERA farms. Low nitrogen surpluses are such that the nitrogen losses to the atmosphere and leaching to the water system and, ultimately, the Baltic Sea are low. Nitrogen leakage may be assumed to be roughly 70 per cent below the average for Finnish agriculture as a whole. The phosphorus deficit also has the consequence that leaching is low. The deficit of 1 kg phosphorus per hectare probably corresponds to the phosphorus that weathering of the soil makes available.





### Why ecological production?

Rekola Farm is very versatile. It started producing according to ecological principles in 1972, which was very early for Finland. The motives for making this brave move were several. Using pesticides, which were used before the conversion, was an unpleasant business, and there was a desire to produce crops that were whole some and clean. One practical consideration that arose as Kalervo took over the farm from his parents was a desire to make the farm self-sufficient, for reasons of economy, as well. Finally, most of the cropland on the farm is silt, or fine sand mixed with silt, i.e., soils that ecological methods can improve.

### Current status?

After over 25 years of biodynamic farming the pH of the croplands has been raised by half a unit, and varies between pH 5.3 and 6.1. Small amounts of dolomite calcium have been applied to the fields, which has apparently helped to raise the magnesium and calcium values in the soil. Some apatite and biotite have also been used. Phosphorus and potassium values remain at about the same level as before. As for mulch, most of the land is classified as mulch-rich.

The new regime was planned with the aim of achieving a whole, the parts of which complement one another as well as possible. Rekola has had animals all the while it has been farmed biodynamically. Mother cows with calves have been part of the picture since 1987, and until a couple of years ago there were about 75 hens on the farm. There is a small flock of sheep. Rekola also has a bakery that uses home-grown flour.

### Future plans

Rekola Farm has continued to evolve since the BERAS project ended. Last year (2010) the weather was warmer than ever before, and there was not enough rain. As a consequence, Rekola had to purchase some silage. On the other hand, the warm weather meant that garden crops did better than ever, as the garden is equipped for irrigation. The harvest was calculated to be about 20 per cent above average.

Einkorn wheat (*Triticum monococcum*) has been introduced, using seed from Hans Larsson, a biodynamic plant breeder in Sweden. Rekola has grown spelt with some success for some time.

In 2011 the farm changed over to the next generation. Kalervo Rekola continues working, but has can now take it easy now and then. The farm will continue according to the same concept, supported as it is by a stable group of customers and consumers.

*(Interview and documentation  
by Pentti Seuri, agronomist)*

Since the time of this interview, management of the farm has passed on to the younger generation. Joonas Rekola and Henri Murto now farm the land, albeit with support and advice from the elder generation. At present, there are no hens or sheep on Rekola, but there may be in the future. Chinese cabbage is back in production, together with other cabbage varieties. Otherwise, the farm continues on its previous course and is a good model for other farmers operating under similar conditions in the Baltic Sea region.

## LATVIA

### ZAGERI

Zageri is located in a hilly landscape in southwestern Latvia, which is not the most intensively cultivated part of the country. The farm raises many different kinds of animals, but also some vegetables and fruit for home consumption. About 40 per cent of the farm's income comes from agro-tourism. The Koesegas operate a guesthouse, equipped with an inviting sauna, that can accommodate up to 30 guests in summer months. The farm's ecologically grown products are featured on the guesthouse menu. The house is separated from the farmyard by a reservoir filled with water from two springs; excess water spills over into a brook.

The farm was family property for generations, but was confiscated when the Soviet Union occupied Latvia. The father was taken prisoner and forcibly exiled to Siberia in 1945. The farm was reinstated to the family only after Latvia regained its independence. Since then, the family has made impressive progress, modernizing and putting all the structures in order, and rebuilding and expanding the original farmhouse. The timber for all the construction work was home-grown, and the family established a small-scale sawmill for the purpose. All this was achieved, despite the fact that Aldis Koesega was severely injured in an accident some years ago. The key factor is the involvement of all seven family members in the effort. The children – two boys and three girls – are now away, getting their education. One of the Koesega sons will soon be graduated from the Agricultural University at Jelgava, outside Riga.

Zageri is an example of a process that is under way in many parts of Latvia today: making up for decades of occupation and oppression. Zageri is one of the success stories and has attracted media attention over the years. On one occasion Latvia's President paid a visit.

#### Zageri.

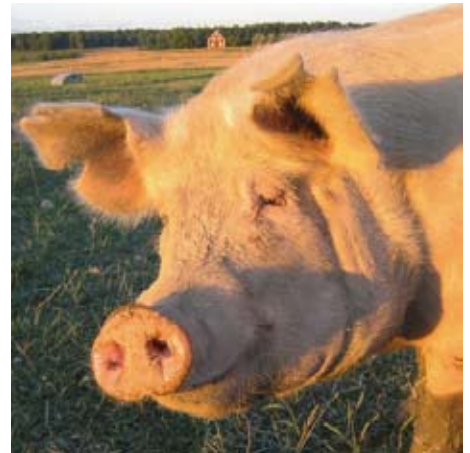
**Farmers:** Aldis and Igita Koesega

**Plats:** Ivander by, Kuldīga distrikt

**Location:** Ivandes pagasts (Kuldīga)

**Area:** 108 ha cropland, 30 ha forest

**Animals:** 18 beef cattle, 3 breeding sows, 49 pigs for slaughter, 13 goats, ducks, 20 hens and 4 horses





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Figure 68. The highly versatile Zageri farm, with many different forms of animal production, has also gone in for agrotourism, which is an important source of income for the Koesega family.

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#### Why ecological production?

When, on a visit to Zageri in the winter of 2008, I asked why the family had converted to ecological production, I was told that Aldis' wife, Igeta, had become overly sensitive to pesticides. Another contributing factor was contact with Mara Bergmani, a pioneer in biodynamic agriculture in Estonia. Among other projects, Bergmani has founded a network of health spas in Estonia, where guests can combine a relaxing visit to a farm with mineral baths, homeopathic regimes and therapeutic massage.

#### Future plans and public policy?

Our discussion of the farm's future expanded to a discussion of the country's future. A few years ago Latvia's Minister of Agriculture asked: What should we do with the one million acres lying fallow today? Many farms have not been taken into use since the Soviet era, and shrubs and weeds have taken over. Other tracts of land have been purchased by foreign interests who plan to establish large-scale industrial agricultural enterprises.



Photo Artur Gransteed

## STRAUMALI AND PAGASTA PADOME, AN ORGANIC DAIRYE

To find out more about how farming is developing in Latvia I visited another of the BERAS farms, namely, Straumali, which is self-sufficient in fodder, with extensive fields of ley and pasture, but feed grain, as well.

As in much of Latvia, gaining access to land is a problem for farmers. Following the collapse of the Soviet Union, many formerly land-owning families regained title to their farms – but without the equipment and installations that modern farming requires. The land had been part of mega-kolchoz complexes, whose giant barns, etc., were now in ruins. Many of the owners, furthermore, are unwilling to lease their land to the farms that are starting up, as they are waiting to sell at higher prices. As a consequence, they will only lease their land for a year or so at a time, which hardly affords a basis for making long-term investments. Meanwhile, the above-mentioned agricultural concerns are able to outbid local farmers when land actually is put on the market.

### Pagasta Padome, an organic dairy

In addition to her farm, where she has one employee, in 1994 Iveta Linina founded a local cooperative dairy, Pagasta Padome, which she also manages. Since 2004, all of the dairy's milk is certified ecological. Despite the economic crisis in Latvia as a whole, the dairy has managed to stay in business. Ten small producers deliver milk to the dairy, which produces pasteurized fresh milk, unripened cheese (very tasty) and butter. Pagasta Padome competes with a large-scale dairy in Riga (about 100 km to the west) on the local market, but uses glass bottles that are returned to the dairy, where they are sterilized and used again. Supermarkets do not like handling bottles for re-use, so Pagasta Padome's milk is sold locally in smaller shops.



Photo Jens Holm

Gårdsnamn: Straumali

Farmer: Iveta Linina

Location: Madlienas (Ogres)

Area: 139 ha (including leased land)

Animals: 42 breeding cows with their calves, 22 young cattle and 30 eco-pigs for slaughter



Photo Erik Lindegren

Figure 69. Industrial-scale animal production, partly owned and operated by foreign-owned corporations, is making an entry onto the market, building on the ruins of Soviet-era kolchoz farms.

### **Why ecological?**

Iveta Linina earned an advanced degree in Food Engineering in the Soviet era. She was in charge of production at a kolchoz that had 2 000 beef cattle. Even then, she was having second thoughts about the nature of her work, and began thinking of a better way. When I ask her “why ecological” and how it all started, she replies without hesitation: “I am a Green”. She has made the move from large-scale down to small-scale, and there is no mistaking her enthusiasm about what she is doing. And she seems to be met with both respect and appreciation by the locals.

### **Future plans?**

Iveta’s answer to the question, ‘What’s next’ is, “Never stop fighting!” The immediate threat today is a firm plans to establish a huge pork ‘factory farm’, quite close to the dairy. Plans an annual production of 35 000 pig carcasses. By the terms of the EU Nitrates Directive, the factory would require 1 000 ha on which to spread the amount of manure so many pigs would produce, and the company has already bought up several hundred hectares. What is more, the business plan envisages a tripling of the annual production. Even at the outset, such a large installation will entail numerous transports of manure from the installation, and emissions to both the atmosphere and local waters. Not only local: the streams in the area feed into the Daugava and, ultimately, the Baltic Sea. A sensitive natural environment, with a wealth of bird life, and expanding ecological agriculture is under threat. The question is whether those who live in the area will be able to tolerate the impacts such an installation will have. Iveta and her neighbors have started an action group to protest the pig factory plans.

### **Policy measures?**

Iveta Linina and the local librarian – both members of the protest group – show me a map and point out eight different locations in Latvia where similar supersized ‘factory

farms’ are currently planned. The group has written to the government and plan to contact EU’s Commissioner for the Environment. Even if the animal factory should manage to contract enough land to fulfill the requirements of the Nitrates Directive, the environmental loads from the installation will be twice or three times those of an ERA farm.

We should recall that Sweden, which does fulfill the directive’s requirements, is – next after Poland – the second-largest source of nitrogen effluents to the Baltic Sea. It seems that the worst-case scenario regarding the future of the Baltic might well become reality.

There is a crying need for a comprehensive overview of this development. How many such factory farms are in the pipeline? Where? What are the potential environmental impacts? Some such animal factories – producing pork and poultry – are already operating, and these need to be evaluated. The same goes for developments in the other Baltic countries and in Poland and the Russian territories, Kaliningrad and the region around St. Petersburg.

There is a trend toward ‘supersizing’ of agriculture in Poland, as well. An American pork-producer and ‘meat packing’ (slaughterhouse) company, has long been established in Poland and has a widely criticized track record with respect to its negligence of environmental regulations – which, for that matter, are lax to begin with.

Thus, clouds darken the horizon – both east and west of the Baltic. The question is whether we in Sweden, Denmark and Finland will be able to correct the system failures in our agriculture – in time. There is no general awareness, let alone consensus, about the need to reform agriculture to attain environmental sustainability; so far, we still content ourselves with patching and mending a system that has demonstrated its failures for decades. Now, there is an additional challenge: Will our neighbors to the east be able to avoid making the same mistakes? The question gains added urgency as industrial agricultural corporations press for entry. Their supersized scale may be reminiscent of the Soviet era, but the motor force behind them is profit.



## CONSERVING RESOURCES – MEASURES AND BENEFITS

**Economic research shows that ecological farms can be just as profitable as conventional farms, once a balance between animal and crop production has been attained. Lower crop yields are offset by the absence of costs for synthetic fertilizer and chemical pesticides. But consumers, too, have to pay for the real cost of the food they eat.**

The examples in the preceding chapter and the farms that participated in the BERAS Project show how it is possible – under widely varying conditions – to operate a farm without either highly soluble synthetic fertilizer or chemical pesticides. Today, there are many such farms, tangible models of how farming can be done in Sweden and the other countries around the Baltic Sea – a system of farming that effectively economizes with finite natural resources and does not pollute the environment with excess plant nutrients and toxic chemicals. It is entirely possible to save the Baltic Sea and still produce enough food of good quality. These goals are within reach, and furthermore promise a good economic return to the region's farmers.

### The ecological foundation

So, what needs to be done to attain these goals? First of all, all agricultural production in Sweden and the other countries around the Baltic needs to be adapted to the laws of ecology, like the ecological and biodynamic farms described here. Simply abstaining from synthetic fertilizers and chemical pesticides is not enough. A truly sustainable farm must operate in accordance with basic ecological principles: renewable energy sources, closed cycles, and biodiversity.

### Mälby Farm

Even a small farm can support a family, if the farm, like Mälby, is able to process its own production for sale to a stable clientele. Harald and Sonja Speer on Mälby Farm in Södermanland, are living proof. The figure shows the fields with varied crop rotation, alternating between nourishing legume-rich ley and extractive grain crops that provide fodder for the animals, which in turn provide fertilizer for the intensively cultivated vegetable crops. The garden, too, follows an extended rotation that includes several years of legume-rich ley and a variety of vegetables and root vegetables. Pasturage for the farm's sheep surround the farmhouse and buildings, and beyond that a little forest. Closest to the farmhouse,



Figur 70. The diversity of plant and butterfly species on a farm increases as soon as one year after conversion from conventional to organic farming systems, according to recently published findings of research teams at the Swedish Agricultural University at Uppsala and the University of Lund. The number of butterfly species continues to grow successively thereafter. Farms that have been under organic regimes for 25 years were found to have twice as many butterfly species as farms that converted only recently

Source: Jonason, et al. (2011) Assessing the effect of time since transition to organic farming on plants and butterflies. *Journal of Applied Ecology* 48:3:543-550. Available online at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3123746/>.



Figure 71a. Juchowo in Poland, 1 400 ha, 350 dairy cows.



Figur 71b. Mälby, a farm of 10 hectares in Södermanland (south-central Sweden).

down toward the lake, is the herbal garden with all the medicinal plants that the farm sells. The garden attracts many visitors, and guided tours are arranged.

Self-sustaining ERA farms range from the very large biodynamically managed Juchowo in Poland, with its 1 400 ha of cultivated land and 350 dairy cows, down to the really small-scale, but all follow the same basic rule: balance between nourishing, humus-building crops and extractive crops, development and enhancement of the soil's fertility, and a recycling-oriented balance between raising crops and keeping animals.

**1. Economizing with nitrogen and other plant nutrients through** recycling within the agro-ecological system to the greatest possible extent: Losses of nutrients must be reduced to a minimum. This requires that the number of animals on the farm be limited by the area of the farm, and that manure and urine be managed in a way that minimizes nutrient losses. Third, it requires the greatest possible recycling of plant nutrients in other material that is removed from the fields.

*Conventionally managed farms will need to take the following measures to attain ecological balance:*

- Farms without animals will have to acquire the number of animals that they can support with home-grown fodder – or collaborate with a nearby farm that keeps animals.
- Farms that have more animals than they can feed with home-grown fodder will have to reduce the size of their flock or herd to match the farm's capacity.

These measures achieve a balance between animal and vegetable production. They also bring about a better regional balance in the numbers of animals. All in all, the overall density of animals per hectare in Sweden will be roughly the same as the average today, but with one principal difference: a greater share of the animals will graze, and their diets will include more coarse fodder than is the case today. From the animals' point of view, the change will mean a better environment and better care.

**2. A solar-based supply of nitrogen** through the use of legumes to fix atmospheric nitrogen, instead of fossil energy: The stores of nutrients in the soil should be freed through growing crops with deep, well-developed root systems, and by stimulating microbial life and soil fauna. Nitrogen and carbon are the keys to building up humus, which in turn is beneficial to microbes, earthworms and other soil fauna, while it improves the capacity of the soil to retain moisture, root development and, ultimately, plants' growth and ability to absorb nutrients, their hardiness and nutritional value.

*Conventionally managed farms will need to take the following measures*

- Cultivation of ley with mixed grass and legumes will have to be introduced on at least 30-40 per cent of the farm's acreage. This includes farms that currently mainly raise cereals and have no animals that eat coarse fodder. In the longer term, it also means that all farms should have some animals that eat coarse fodder, albeit some of the ley can be ploughed under as green fertilizer.
- Ley needs to include legumes. Many conventional farms that cultivate ley grow mostly grass and import their nitrogen in the form of synthetic fertilizer to the grassland – at great cost, money that can be saved. Legume-rich ley on 30 per cent of its area will make a farm self-sufficient in nitrogen, provided that the management of manure and the other methods used all minimize nitrogen losses.

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*Any farm, big or small, can be managed according to ecologically sustainable principles. Here we see Sebastian Huiseman, operations manager, in a state-of-the-art barn on the biodynamic farm Juchowo in northwestern Poland. The farm has 1 400 ha of ploughed cropland and 350 dairy cows plus own replacement of livestock, animal production for meat, and a variety of crops with cultivated ley and fodder grain that covers the farm's fodder needs, plus bread grain and garden farming, the produce of which is sold in the farm shop.*

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**3. Nutrient cycles** – both the binding and freeing of nitrogen and other organically bound nutrients – have to be managed so that the amount of nutrients available at any given time corresponds to crops' nutrition needs. When this balance is achieved, nutrient losses to the environment can be reduced to very low levels.

*Necessary measures:*

- Every farm has to plan a crop rotation that is specifically adapted to the location of the farm, a plan for recycling of manure and urine, among other technical measures.
- Ley periods need to continue several years and have both grass and clover so that cropland does not gain access to nitrogen too quickly when the ley period ends. The choice of crops, the technique for working the soil and the timing of various measures have to be adapted to the local climate and soil conditions. More ley cultivation presumes a larger volume of meat production from ruminating animals raised on coarse fodder, and a corresponding reduction in the volume of pork and poultry.

A varied crop rotation is essential in order to avoid infestations of pests, fungi and weeds. This will also include fodder crops like oil seed, peas, beans and others compensating for no imported concentrates,

As the examples have shown, it is entirely possible to manage an ecologically well adapted farm successfully without using any chemical pesticides. The keys are variety, diversity, just enough plant nutrients and mechanical weed control.

It is possible, on the basis of the model crop rotations for an ERA farm and the examples from the BERAS project, to outline an agricultural scenario for Sweden as a whole. When doing so, it is important to take account of the extreme variation in production conditions in different parts of the country.

In a country like Sweden, the requirement that all farms cultivate ley with grass and legumes on at least one-third of their acreage, in addition to the areas with longer periods of pasturage, would mean that something on the order of 60 per cent of arable land would be producing ley at any given time, as opposed to 45 per cent today.

Furthermore, arable land in ley would be redistributed over the country, with more ley on the plains and on farms that today are totally specialized in cereal production.

Region	Acreage 1000 ha	Model crop rotation	Share of ley + pasturage: target and (current)
Northern Sweden (Norrland)	270	Ley Ley Ley Cereals Cereals/ green ensilage	80 % (80 %)
Forested parts of mid- and southern Sweden (Svealand, Götaland)	700	Ley Ley Ley Cereals Cereals	75 % (63 %)
Marginal cropland in southern Sweden (Götaland)	300	Ley Ley Cereals Cereals/peas etc. Cereals/green ensilage	70 % (41 %)
Plains of southern Sweden (Götalands)	1 400	Ley Ley Cereals Cereals Peas, beans, root vegetables Cereals	50 % (27 %)

Table 4. Distribution of cropland uses and model crop rotations appropriate for Sweden, by region.

The equation presumes meat production equal to current consumption. Lower production of feed grain and more acreage in ley would require that one-third less pork would be produced, while beef production, based on coarse fodder, would increase by a corresponding volume so that total meat production would be the same. The net result would be about the same volume of pork as Sweden produced in the 1950s. When ley is used as a source of nitrogen, it becomes more profitable to raise beef and dairy cows on a diet largely consisting of coarse fodder.

### **Better returns to the farmer – and to the country**

So far, we haven't taken account of the costs of conversion itself. They will depend on how quickly the conversion takes place.

If a farm converts in pace with the depreciation of existing buildings and installations and equipment, and new investments are made successively, the costs of conversion should not be burdensome. Economic studies have shown that profitability need not be any lower for an ecological farm, once the balance between animal and crop production has been attained. As we have noted, lower yields are offset by not having to pay for fertilizer and chemical pesticides. The situation may be different for farmers in southern Sweden who have specialized in intensive grain production.

Widespread conversion to an Ecological Recycling regime would also enliven the countryside, with a greater variety of more versatile farms.

Such a development is fully achievable in all the countries in the Baltic Sea region.

The countries of the Baltic Sea region might become models for other countries – not least those in the European Union, where conversion to ERA might solve the mounting problems of high costs for surplus production and increasing environmental impacts from agriculture. Ecological Recycling Agriculture in the Baltic Sea region, based on local and renewable resources, might also be a model for farmers and policy-makers in many parts of the world, where ecological methods, adapted to a broad range of local conditions, are being introduced as an alternative to conventional agricultural systems.

## SUMMARY

All natural ecosystems must obey the basic rules of ecology, and so must we human beings obey them whenever we intervene into ecosystems to make use of the resources that Nature provides.

- We can learn from historical example how to change our ways so that we no longer destroy the resources on which our lives depend, but instead restore those resources and generate fertile soil.
- But, historical examples also demonstrate how quickly we humans can deplete what natural processes have built up.
- Finite reserves of oil and minerals are being used up, with increasing pollution of the environment as a consequence.
- Agriculture's current dependence on fossil energy and conventional cultivation methods with specialization of farms to produce either animals or crops, and thus linear flows of energy and resources, lead to depletion of resources, eutrophicated lakes and seas, climatic distortions, degraded soils and food that is not nutritious enough.
- Arable land is shrinking; meanwhile, the planet has more and more mouths to feed.
- Real farms within the Baltic Sea area show us how ecological agriculture based on closed cycles of energy and resources, that uses organic fertilizer and diversified crop rotations with humus-generating, symbiotically nitrogen-fixing grass-legume leys, can restore fertility to the soil, restore life to the sea, reduce climate-altering emissions and provide nutritious food.
- Short distances between food production and consumption, and processing facilities near the source yield additional environmental advantages in the form of shorter transports and provide economic stimuli and employment opportunities in rural regions, which will benefit farming and food industries of the future.
- Conversion of farming to Ecological Recycling Agriculture, as described here, and more, and more vital, interaction between communities and their rural surroundings throughout the Baltic Sea region can save the Baltic Sea – and set an inspiring example for the rest of the world.
- We, too, in our role as consumers, will need to make some changes in our lifestyles and in the foods we choose to put on our tables. A fundamental reform of how we farm, coupled with changes in our diets, with less meat and more greens and root vegetables from ecological recycling farms, would make it possible for the planet's resources to feed everyone in the world, now and well into the future.

## REPORTS FROM THE BALTIC SEA PROJECT BERAS AVAILABLE ON WWW.BERAS.EU

### Reports

The results from research carried out in BERAS project (2003-2006) form the basis for the current BERAS Implementation project (2010-2013) and are made available in seven reports

[Baltic Ecological Recycling Agriculture and Society \(BERAS\) – Executive Summary.pdf](#)

BERAS executive summary, Granstedt, A. 2007.

(Finns ej i tryckt form)

**Beras report nr 1** – Local and organic food and farming around the Baltic Sea

[beras 1 – local and organic food and farming around the Baltic sea – ekolantbruk40.pdf](#)

Ekologiskt lantbruk nr 40. Sepänen, L (ed.). July 2004.

**Beras report nr 2** – Effective recycling agriculture around the Baltic Sea

[beras 2 – wp3 – effective recycling agriculture around the baltic sea.pdf](#)

Ekologiskt lantbruk nr 41. Granstedt, A., Seuri, P. and Thomsson, O. December 2004.

**Beras report nr 3** – Economical studies within WP3.

[Economical studies within WP3.pdf](#)

Ekologiskt lantbruk nr 43. Possibilities for and Economic Consequences of Switching to Local Ecological Recycling Agriculture, Sumelius, J. (Ed). 2005

**Beras report nr 4** – Obstacles and solutions in Use of Local and Organic Food

[Obstacles and solutions in Use of Local and Organic Food.pdf](#)

Ekologiskt lantbruk nr 44. Kakriainen, S., von Essen H. (ed.). Augusti 2005.

**Beras report nr 5** – Environmental impacts of ecological food systems – final report from BERAS

[Environmental impacts of ecological food systems – final report from BERAS, pdf](#)

Ekologiskt lantbruk nr 46. Granstedt, A., Thomsson, O. and Schneider, T. January 2006.

**Beras report nr 6** – Approaches to Social Sustainability in Alternative Food Systems

[Approaches to Social Sustainability in Alternative Food Systems.pdf](#)

Ekologiskt lantbruk nr 47. Sumelius, J. & Vesala, K.M. (eds.).

December 2005.

**Beras report nr 7** – The Power of Local – Sustainable Food Systems around the Baltic Sea

[The Power of Local – Sustainable Food Systems around the Baltic Sea.pdf](#)

Ekologiskt lantbruk Eds: Kahiluoto, H., Berg, P.G. , Granstedt, A., Fisher,

H. & Thomsson, O June 2006

Rapporterna är publicerade vid Centrum för Uthålligt Lantbruk (CUL)

Sveriges Lantbruksuniversitet.

#### **BERAS-related peer-reviewed scientific publications**

- **Granstedt, A., Seuri, P and Thomsson, O. 2008.** Ecological Recycling Agriculture to Reduce Nutrient Pollution to the Baltic Sea. *Journal Biological Agriculture and Horticulture*, 26(3) 279-307.
- **Granstedt, A., Tyburskij, J., Stalenga J. 2007.** Nutrient Balances in Organic Farms. Baltic Sea project BERAS (Baltic Ecological Recycling Agriculture and Society), results from Poland. In: Scientific Agricultural conference Poznan August, 2007.
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- **Helmfried, H., Haden, A. and Ljung M. 2007.** The Role of Action Research (AR) in Environmental Research: Learning from a Local Organic Food and Farming Research Project. *Journal Systemic Practice and Action Research*.
- **Larsson, Markus 2012.** Environmental Entrepreneurship in Organic Agriculture in Järna, Sweden, *Journal of Sustainable Agriculture*, 36:2, 153-179
- **Larsson, M., Granstedt, A. and Thomsson, O. 2011.** Sustainable Food System –Targeting Production Methods, Distribution or Food Basket Content? In *Tech – Organic Food and Agriculture / Book 1*
- **Larsson, M. and Granstedt, A. 2010.** Sustainable governance of the agriculture and the Baltic Sea – agricultural reforms, food production and curbed eutrophication. *Ecological Economics*, vol. 69, no. 10, 15 August 2010.
- **Nousiainen, M., Pytkinen, P., Saunders, F., Seppinen, L., and Vesala, K.M. 2009.** Are Alternative Food Systems Socially Sustainable? A Case Study from Finland. *Journal of Sustainable Agriculture*, Volume 33, Issue 5.



Summary of the main results from the project

## BERAS- BALTIC ECOLOGICAL RECYCLING AGRICULTURE AND SOCIETY

### **A research and development project with part support from EU (BSR INTERREG IIIB) 2003-2006**

The agricultural and food sector in Sweden and several other western European countries is today characterised by specialisation with crop production based on the use of artificial fertilizers on farms with no livestock and animal production on other farms concentrated to certain regions; a food system characterised by long transports of agricultural products, animals and foodstuffs and the use of non-renewable energy in the food chain. These characteristics are all major sources of water pollution, greenhouse gas emissions and biological diversity degradation. This situation is described in the background report to the BERAS – project. It is based on the analysis of plant nutrient balances and nutrient flows on farm, regional and country level in Sweden and Finland by Granstedt (2000). The environmental situation in the Baltic Sea mirrors this non sustainable use of natural resources by humans.

The aim of the BERAS project has been to build up a knowledge base and competence for a more sustainable life style within the whole agriculture and food sector. In the project, examples of ecological and local/regional production, processing, transportation and consumption of food products have been evaluated. On some of the 48 reference farms representative of ecological recycling agriculture and the ten local food initiatives included in the project the whole food chain has been studied. The BERAS project has addressed the need to analyse the environmental and socio-economic consequences of ecological recycling agriculture as well as the opportunities and obstacles facing the various actors in the food system, i.e. producers, processors, traders and consumers. Studies of various aspects of the whole food system have been carried out with 20 partner institutions and more than 50 academic researcher in all 8 EU member states around the Baltic Sea: Sweden, Finland, Denmark, Germany, Poland, Lithuania, Latvia and Estonia.

The project started March 2003 and ended March 2006. The work included 5 Work Packages: WP1 (Case studies report 1 and 4), WP2 (Environment report 2 and 5), WP3 (Economy report 3), WP 4 (Sociology report 6) and WP 5 (Dissemination and synthesis report 7 and 8). To date seven reports have been published by the

Swedish University of Agricultural Sciences (SLU) through the Centre for Sustainable Agriculture (CUL). These and the executive summary are available at: [www.beras.eu](http://www.beras.eu)

*Below are the main conclusions from the BERAS work:*

**1. The main reason for the increased load of nitrogen and phosphorus from agriculture to the Baltic Sea is the specialization of agriculture with its separation of crop and animal production.** This restructuring of the agriculture sector took place through out the Scandinavian countries after World War II and has resulted in farms with a high density of animals and great surpluses of plant nutrients, particularly in certain regions in Sweden, Finland and Denmark (WP2, BERAS report 2, IV).

**2. A specialization of agriculture in Poland and the Baltic states** corresponding to the changes in Sweden, Finland and Denmark would lead to an increase of nitrogen pollution to the Baltic Sea by more than 50 percent (WP2, BERAS report 5,II).

**3. Agriculture based on the principles of ecological recycling** would, according to the results in the BERAS project, lead to a decrease in the calculated nitrogen leaching by half as well as a significant reduction in the loss of phosphorus. Ecological Recycling Agriculture (ERA-agriculture) was defined as an agriculture system based on local and renewable resources with an integration of animal and crop production (on each farm or farms in close proximity) so a large part of the nutrient uptake in the fodder production (in Europe on about 80 % of the arable land) is effectively recycled. This in effect means that each farm (or farms working together with closed recycling) strives to be self-sufficient in fodder production which in turn limits animal density and ensures a more even distribution of animal to most farms (WP2, BERAS report 5, II).

**4. Nitrogen losses would diminish more in countries that have an intensive agriculture** than in the Baltic countries and Poland where today there is a more extensive form of agriculture. In Sweden the potential for diminishing nitrogen losses are calculated to be between 70–75% (WP2, BERAS report 5).

**5. The total output of animal and crop products would not have to decrease** with such an agriculture reform in the Baltic Sea Basin, if the production level on the documented ecological recycling farms in Sweden is taken as standard. (WP2, BERAS report 5, II).

6. **The proportion of leys in a future ecological recycling agriculture would increase** in areas that are now mostly specialised in grain production. Leys with both clover and grass would have to be produced on all farms. This would increase the chances of diminishing plant nutrients' leaching, building up and protecting the humus content in soil and promoting biological diversity (WP2, BERAS report 5, II).

7. **Increased ley production would result in the reallocation of meat production.** Production of meat from non ruminant animal (poultry, pigs) would decrease by half, while beef production would increase correspondingly –assuming today's level of meat consumption. (WP2, BERAS report 5, IX).

8. **Local production, processing and distribution of food products from ecological recycling agriculture could diminish primary energy consumption and green house gas emissions** compared to the current conventional food system. According to a scenario based on studies of the ecological local food chain in Järna and the average consumer in Sweden, the per capita consumption of primary energy would decrease by 40% and the production of green house gases would decrease by 20 % in the food chain (WP2, BERAS report 5, V, IX).

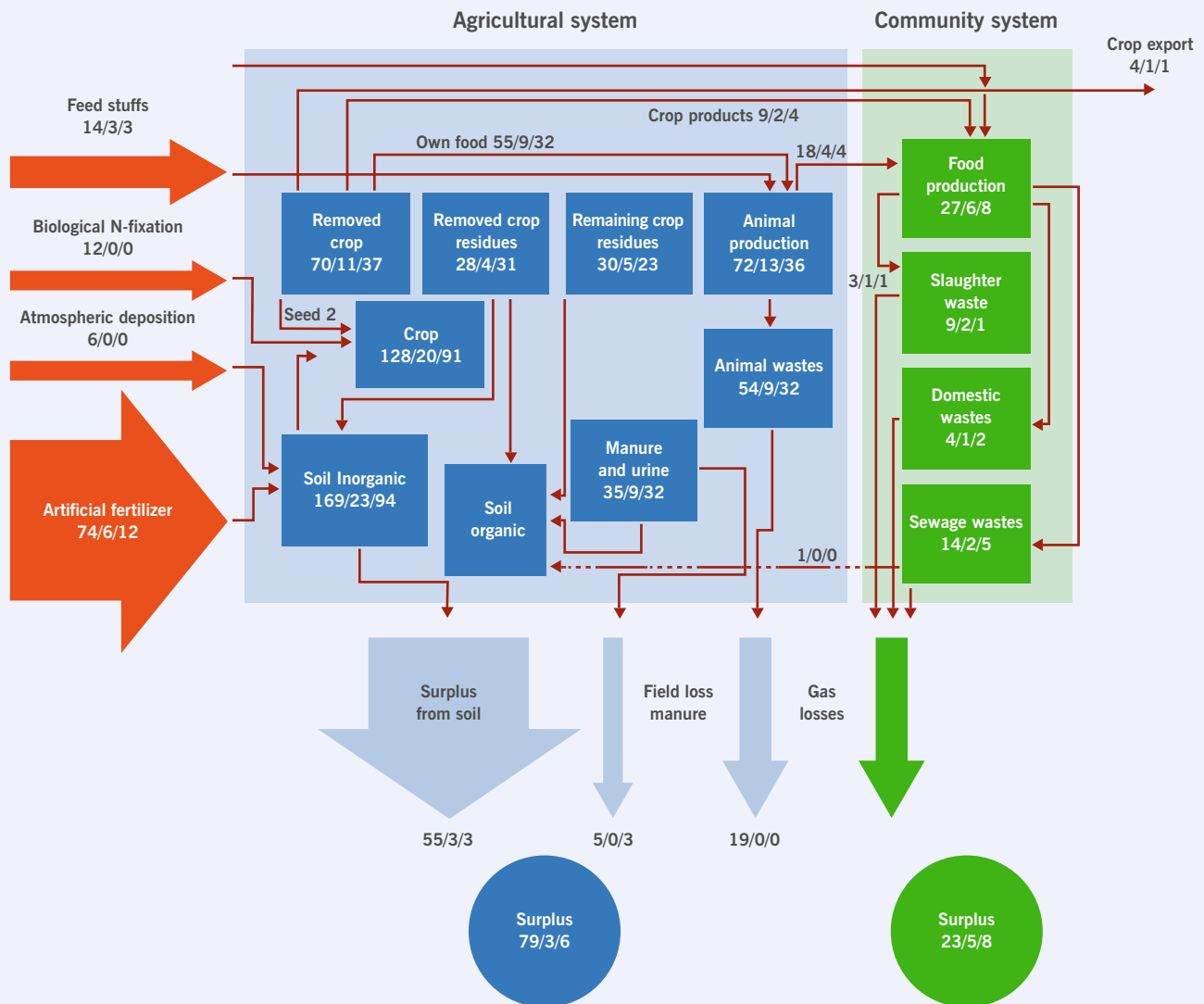
9. **A more vegetarian food consumption, (80% less meat and 100% more vegetables) could decrease energy consumption** by 60% and green house gas emissions. The area in Sweden required for food production would be reduced by by 50% if the area used for production of imported fodder is also included. The per capita nitrogen surplus in Sweden would be reduced by 65% in this more vegetarian scenario when compared to today's conventional food consumption. (WP2, BERAS report 5, V, IX).

10. **An ecological and locally oriented food chain leads to freedom from chemical pesticides,** greater diversity in the production and more grazing-based animal husbandry. All of this promotes biodiversity in the farm landscape (WP2, BERAS Report 5, VI). Agriculture based on the integration of animal and crop production and an animal density limited to on-farm self sufficiency in fodder production would prevent the disintegration of the agricultural landscape in parts of the Baltic Sea basin such as Poland where the agricultural landscape is still characterized by a high degree of diversity. In the parts of the Baltic States where large-scale agriculture production from Soviet times has collapsed and in the industrialized and grain dominated areas in Sweden, Finland and Denmark, introduction of such agriculture could lead to a restoration of the agricultural landscape (WP4, BERAS report 4).

**11. Economic studies at the farm level show higher production costs** when environmental costs are included (internalized) in the production costs. This includes, among other things, the restrictions on using fodder concentrates. There is a 12% lower production per cow without soy protein. Also limiting the number of animals to the farms own fodder-producing capacity has economic consequences. In the Järna study the cost for milk production was 19% higher compared to conventional agriculture (0,5 – 0,6 SEK per kg milk). The food expenditure for the 15 Järna households with mainly ecological and to a great extent locally produced food was on average 25% higher. However, there was great variation depending on the food profile. Conventionally produced food does not include the environmental costs. They are instead pushed towards the future or to other parts of the world (WP3, BERAS report 3).

**12. Practical examples of ecological recycling agriculture,** local food processing, cooperation with schools, ecological tourism and the development of local markets have been documented in the eight countries of the project. The studies showed how private initiatives, raised awareness concerning the significance of the food chain for the environment and a more lively cooperation between people can contribute to a more ecologically, economically and sociologically sustainable society. Such a society provides more job opportunities in the countryside and strengthens the local rural economy. This is expected to be of great importance for saving and further developing a vibrant rural culture and improving the quality of life in the Baltic Sea region. Establishing such agriculture can have such positive effects both within the more impoverished rural areas in the new EU member countries as well as in the depopulated rural areas in countries with a more industrialized and specialized agriculture (WP4, BERAS report 6).



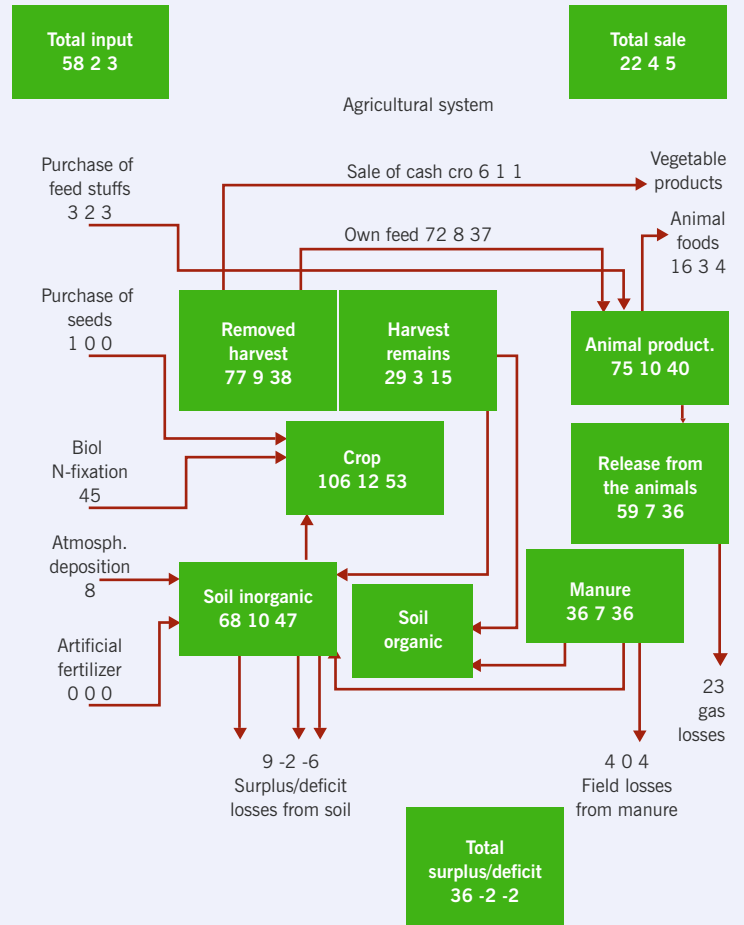


Appendix Figure 1 Estimated flows of nitrogen, phosphorus and potassium, kg/ha and year in Swedish agriculture, based on available public statistics (Statistics Sweden) for the period 2000-2002 . The average nitrogen utilization is only 30 per cent. The difference between total input in the form of mineral fertilizer (74 kg), atmospheric deposition (6 kg), biological nitrogen fixation (12 kg), imported fodder (14 kg) and recycled waste products, on the one hand, and food production (32 kg) is lost to the surrounding environment, to the extent it is not temporarily stored in the soil. Of this calculated surplus (79 kg), 55 kg is released from the soil, and an estimated 19 + 5 kg comes from animals. The figures are a calculated mean value for all Swedish farmland. There are major differences, however, between specialized grain producing farms (considerably lower losses) and specialized animal production (up to double the total mean losses). Source: BERAS report 2. Granstedt, Seuri and Thomsson, 2004)

<sup>1</sup> Granstedt, A. 2000. Increasing the efficiency of plant nutrient recycling within the agricultural system as a way of reducing Pollution to the Baltic Sea.. Agriculture, Ecosystems & Environment 1570 (2000) 1–17. Elsevier Science B.V. Amsterdam.

<sup>2</sup> Granstedt, A., Seuri, P., Schneider, T. & Thomsson, O. 2008. Ecological Recycling Agriculture to Reduce Nutrient Pollution to the Baltic Sea. Journal Biological Agriculture and Horticulture.

Flow of N/P/K kg ha<sup>-1</sup> in the agricultural - ecosystem Yttereneby-Skilleby (0.6 animal unit/ha) farm 2002-2003



Calculation factors	N	P	K	Given figures	N	P	K
Store losses from manure	0.4			Purchase to anim.pro	3	2	3
Field losses from manure	0.1	0.05	0.1	Purch. seeds	1	0	0
Fodder/animal production	4.6	3.0	10	Biol. N-fix	45		
				Atmosph. dep.	8		
				Artificial fertilizer	0		
				Crop export	5.5	1	1
				Export of animal prod	16	3	4
				<b>Calculated values</b>			
				Own feed	72	8	37
				Harvest remain	29	3	15

Appendix Figure 2. Flows of the nutrients, nitrogen (N), phosphorus (P) and Potassium (K), kg per ha and year, on the experimental farm Skilleby-Yttereneby in Järna, Sweden, The farm is representative of the ERA farms studied in the BERAS project in 2003-2006. Flow analyses of this kind are drawn up for each of the participating farms as a means to monitor and bring the flows under control. Source: Granstedt, Seuri & Thomsson, 2004.









In this book *Artur Granstedt*, Ph.D. in Agronomics and Associate Professor at Södertörn University, Sweden, and Coordinator of BERAS, the Baltic Sea project at the University, describes how ecologically adapted farming based on local recycling and renewable energy sources can reduce the eutrophication of the Baltic Sea and even help to reduce global warming. Widespread conversion to organic farming methods would furthermore stop the spread of toxic chemicals on farmland, benefit biodiversity and stimulate social and economic development in rural areas in the Baltic Sea region.

The book starts with a description of the ecosystems that support the health of the biosphere – terrestrial and marine, the climate, and global food production. Granstedt also gives a historical overview of agricultural practices, noting the various ways in which human activity alters the natural order of things and, if we are not mindful, can deplete the resources that support our existence. But he also gives examples of how we can turn negative trends to the better, how we can restore fertility to the soil and bring depleted land to bloom once again and produce nourishing food that can feed the world.

Artur Granstedt writes on the basis of decades of experience as an organic farmer, researcher, adviser and teacher of ecologically sustainable agriculture. The book reports the results of field trials and evaluations on farms in eight countries around the Baltic Sea that were conducted in the project, Baltic Ecological Recycling Agriculture and Society (BERAS). This comprehensive project, which was supported in part by funding from the European Union, is now continuing in an implementation phase, focusing on how agriculture throughout the region can be converted to profitable and ecologically sustainable methods of production.

Publication of the book has been made possible through a grant from the European Regional Development Fund (ERDF) to the BERAS project at Södertörn University and the Biodynamic Research Institute in Järna, and funding from the Swedish Government and the Swedish Research Council Formas.



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**BERAS** implementation  
Baltic Ecological Recycling  
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