6.

APPROACHES TO SUSTAINABLE AGRICULTURE I

Ecological farming

by Bengt Bodin

6.1 Ecological farming

Ecological farming emerged as a reaction to the orientation towards industrial systems in the agricultural sector. Many viewed these changes as biologically untenable. Ecological farming took a stand against this development and excluded the use of pesticides and chemical fertilizers, products which were seen as a hazard to many important natural functions, as well as to mankind's well-being.

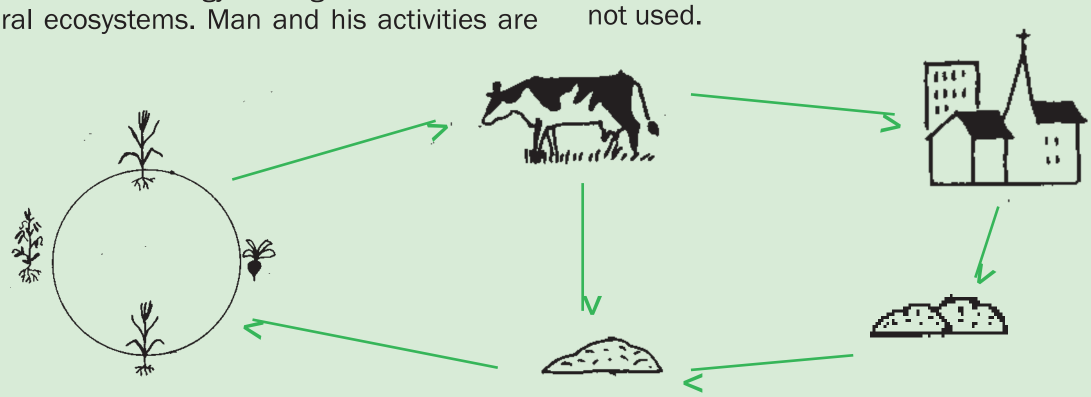
It is, occasionally, maintained that current ecological farming methods have a historic tradition. The implementation of techniques and farming systems used during the nineteenth and early twentieth centuries is often held up as a model for ecologically sustainable systems. This is wrong. There are numerous examples of systematic mismanagement during this period which led to the depletion of farmland, and it is widely known that agricultural production often was insufficient. Starvation was commonplace and famines occurred. During the mid-nineteenth century, this led to substantial emigration from Europe. Then, the population in Europe, as elsewhere on the globe, was only one-quarter of today's level.

Certain characteristics of nineteenth century farming systems were, nevertheless, refined during the early twentieth century and will become part of a future ecologically adapted system of biological production. These practices today have names, such as alternative production and ecological agriculture. They refer to:

1) plant nutrient management without chemical fertilizers

Ecological farming

Ecological agriculture refers to a self-sustaining agroecosystem, approaching the characteristics of material and exergy management of mature natural ecosystems. Man and his activities are integrated in the system; the production is characterized by a holistic view of plant and animal production. Pesticides and chemical fertilizers are not used.



1. CROP ROTATION
A crop rotation scheme is normally more than four years. Its purpose is to reduce weeds as well as insect and pest infestations, to increase nutrient balance of the soil, to improve soil structure and to produce cereals for human food and fodder for animals.

2. ANIMAL HUSBANDRY
Animals, mostly cattle or grazing animals, allow the fodder to be used efficiently. Cattle or sheep will use additional areas on a farm not suitable for crop cultivation. This will contribute to landscape and biological diversity. The proper and humane care of animals is also emphasized in ecological farming.

3. NUTRIENT RECIRCULATION
Nutrients are recirculated to the extent possible. Manure from animals is returned to the soil. Nutrient leakage from soil is reduced by proper cultivation of crops, including use of catch crops, a high degree of winter grown land etc. Tilling of soil is reduced as compared to conventional farming.

Sustainable Agriculture

Requirements of future global agriculture

By the year 2025, the global population will increase to some 8.5 billion. However, the capacity of available resources and technologies to satisfy the demands for food and other agricultural commodities of this growing population remains uncertain. Agriculture has to meet this challenge, mainly by increasing production on land already in use and, moreover, by avoiding further encroachment onto land that is only marginally suitable for cultivation.

Major adjustments are needed in environmental and macroeconomic policies, at both national and international levels, in developed as well as in developing countries, to create the conditions for sustainable agriculture and rural development. The major objective is to increase food production in a sustainable way and to enhance food security. This will involve appropriate and new technologies, proper natural resource management and environmental protection (Agenda 21).

The concept of food security

The concept of food security used in its most general form means a state of affairs where all people have access to safe and nutritious food to maintain a healthy and active life (FAO, 1996). Governmental agricultural policies in all countries around the Baltic Sea are based on self-sufficiency in foodstuffs. This will, among others things, require adoption of a policy for securing the livelihood of farmers who are the food producers.

The World Food Summit

On November 13-17, 1996 the United Nations Conference on World Food Security was held in Rome, Italy. The Conference discussed and signed the 'Rome Declaration on World Food Security' and elaborated on a Plan of Action.

Among the key issues discussed were the need for economic, social, and political reforms; the need for sustainable agriculture, forestry and fishing and the role of world trade for food security. The directions in the Agenda 21 document were confirmed.

The Conference considered it intolerable that more than 800 million people throughout the world do not have enough food to meet their basic needs. Poverty was singled out as the major cause of food insecurity. It was further underlined that food may not be used as an instrument for political or economic pressures.

> *"- we will pursue participatory and sustainable food, agriculture, fisheries, forestry and rural development policies and practices in high and low potential areas, which are essential to adequate and reliable food supplies at the household, national, regional and global levels, and combat pests, drought and desertification, considering the multifunctional character of agriculture"*

(From the Rome Declaration on World Food Security)

Properties of sustainable systems

A sustainable process is one that can be maintained indefinitely without progressive diminution of essential qualities inside or outside the system area. Some key features are as follows:

1. Sustainable systems are equitable.
2. Sustainable systems are efficient.
3. Sustainable systems are flexible. In the case of agriculture, it can be less vulnerable to expected variations in weather and periodic infestations of insects and diseases.
4. Sustainable systems are principally self-sufficient. Use of locally available labour, soil, water, energy, etc. makes them less vulnerable to import embargoes and other critical factors.
5. Sustainable systems are integrated in synergistic functions. National, regional and local systems complement each other so that waste and joint products from one process can be shared or redirected to other systems within the region with minimum disruption.
6. Sustainable systems and society's institutions are consistent.

Properties of sustainable agriculture

Sustainable agriculture means the successful management of resources to satisfy human needs today without endangering the ability of future generations to satisfy their needs. In this context, sustainable agriculture is a production system that attempts to provide long-term sustained yields through the use of ecologically sound management technologies such as crop diversification, recirculation of plant nutrients and biological pest control.

Sustainable agriculture is thus:

1. Ecologically sound: the quality of natural resources within an environmentally sound system is maintained or enhanced.
2. Economically viable: farmers can produce enough food for self-sufficiency and obtain an adequate income.
3. Socially just: resources and power are distributed in such a way that the rights to land use, adequate capital, market opportunities and technical assistance are assured.
4. Humane: all forms of life (plant, animal, human) are respected.
5. Adaptable: rural communities are capable of adjusting to constantly changing farming conditions.

2) weed and pathogen control without pesticides.
3) integrated plant and animal production

Nutrient management is mainly achieved by returning manure to farmland, and weed and pathogen control through crop rotation.

Ecological farming in the Baltic region occurs on only a small percentage of the total farming area. Sweden, which has percentage-wise the largest area in the Baltic region devoted to ecological farming, had only reached some 3 per cent of all farmland, about 2,000 farms, or slightly less depending on the criteria used. The political goal is to reach the ten percent level by the year 2000. To achieve this, different forms of subsidy have been created. The support is justified by reasons such as the relatively high labour intensity, the greater risks taken and the lower yields produced in comparison with conventional farming.

Provided that the special conditions stipulated by the control organizations are met, a higher price for the products can also be had. The ecologically grown food is then given a special label. The label can be used for grain, vegetables and animal products. Prices are, on average, 15 per cent above the price for conventionally produced food. The questions whether the higher price reflects higher product quality and whether the reasons given in justification of the subsidies are true have been the subject of heated debate. The production of ecological goods is seen as a matter for the market to regulate.

Many customers are willing to pay the higher prices because they like the biological production methods better, because they believe the products to be more healthy since no pesticides have been used, or, when it comes to meat, because of ethical reasons.

6.2 Recycling of nutrients

Most of the plant nutrients that the agricultural sector uses, are recycled within the agricultural system itself. Crop debris and farmyard manure are returned to the soil. In traditional farming, however, there are important exceptions.

One significant exception is due to farm specialization in animal or crop production. Here the animal farms have a plant nutrient surplus due to feed purchases. These surpluses cause losses via leaching and ammonia emissions. At the same time, the crop farmers compensate for their nutrient deficits by purchasing mineral fertilizers.

Another exception relates to the fact that about 30 per cent of plant nutrient capital is, currently, not being recycled. It goes along with the foodstuffs to the cities and communities. The plant nutrient in the food then ends up in waste; mostly sludge in waste-water treatment plants. Only a very small amount of this is returned to the farms.

Ecological farms are not using artificial fertilizers and have to be very careful in their plant nutrient management. This is achieved through a series of practices. Crop cultivation and animal farming are integrated and manure from the animals is returned to the soil. Extensive losses of nutrients through leaching is avoided as long as possible. Finally, the addition of nitrogen to the soil is achieved through crop rotation with regular use of leguminous plants which have a good capacity for nitrogen fixation. The phosphorus needed is released from the soil through normal natural processes and by adding rock phosphorus. Occasionally, minerals such as potassium salts are added to the soil.

It is apparent that ecological farming must be developed to embody a production system which is sustainable in the long run. This means that it must take its cues from the principles of highly developed ecosystems. This is especially true with regard to material and exergy management. As mentioned the presently practised system of ecological farming has one big leak when it comes to nutrient circulation. That is the close to 30 per cent of nutrients that leave the farm with the products, the food.

A sustainable cropping system requires that the plant nutrients in the food must be returned to the farmland. This is especially important as far as phosphorus is concerned. Today's ecological farming does not meet this requirement. The reasons are numerous and, in most cases, beyond the farmers' control.

Urbanization, for instance, has brought about a situation where returning the waste products would be extremely energy-demanding. This applies both to toilet waste from individual households and sludge or chemically precipitated phosphorus from waste-water treatment plants.

Additionally, the waste, especially the sludge, is quite often contaminated with dangerous metal ions such as cadmium, mercury and lead; copper and zinc may also appear in excessive amounts. The heavy metals largely come from industrial waste water that is mixed with household waste water in the treatment plants. In Sweden today – and probably the figures are no better elsewhere – one would require a considerable reduction of cadmium in sludge, occasionally as much as a thirty-fold reduction, to avoid a build up of the element in the soil by returning the sludge to the fields.

Human urine contains the greatest proportion of excreted nutrients. The use of urine-separating toilets with a facility for collecting urine for returning to farmland would thus have the potential for closing a large part of the nutrient flow. However, there are some problems here also. Disadvantageous organic substances such as halogenated hydrocarbons, pathogenic organisms and even excreted medicines are occasionally present. It is not yet known to what degree these substances are absorbed by crops.

The extraction of plant nutrients from sewage is insufficient, even in the best sewage treatment plants. This is especially true for potassium and nitrogen. In addition, there is a certain degree of scepticism among market actors towards the use of human toilet waste as it is assumed to lead to buyer boycotts.

There are several approaches to remedy the shortcomings in nutrient recirculation. For the rural population a management of toilet waste that allows nutrients to be returned to fields is relatively straightforward. For cities an important strategy is to separate industrial and household waste. This will reduce the content of heavy metals in the sludge considerably. Again large changes in existing structures will be needed to accomplish this.

6.3 Pesticide-free agriculture

Ecological agriculture does not use chemical biocides and thus weeds, fungi and insects have to be controlled by biological methods. Using a crop rotation scheme well adapted to the host range of parasites and local conditions seems to be quite successful for most crops. The lower amount of nutrients used in ecological farming reduces the risks but it is often necessary to use mechanical weeding, especially for perennial weeds.

There are also other advantages. Conventional pesticides not only kill damaging organisms: beneficial ones contributing to the protection of the crop are also affected. There is a need, however, for much more knowledge in order to achieve efficiency in the biological protection of crops.

Some species are difficult to grow without artificial protection. The potato, for example, usually gives much lower yields when produced ecologically because of persistent attacks of potato blight, which cannot yet be countered by biological methods. Oil seed production is even more difficult. Crops such as rape seed cannot be cultivated at present without the protection by pesticides against insect attacks.

6.4 Integrated crop and animal production

In ecological agriculture, animal and crop farming are preferably integrated. One reason is that specialized farming of either one or the other – crops or animals – is hard to get environmentally acceptable, as was explained above. But even more fundamental is the fact that good crop rotation, required for proper nutrient management, contains a considerable proportion of hay containing grass and clover or alfalfa. This may be used as fodder for cattle, horses, sheep, etc. and to some extent for pigs and poultry.

At present, large areas are used for growing fodder grain, such as barley, for animals and which could just as well be used for growing cereals for human consumption. In this way the total production capacity would be better utilized in farming.

There is, however, a lower limit to the decline of animal production. If the nitrogen supply for plant production is to come from nitrogen-fixing leguminous plants, then ruminant animals are natural elements in future ecological production. On grass-producing land which cannot be ploughed, ruminants would contribute to improved nutrient and exergy management. It is likely that pasture management practices for these areas will include several different animal species. The combination of pasture vegetation types and species is also likely to change in order to make better use of soil profiles and the growing season.

6.5 Yields in ecological farming

The per hectare yields for grain crops in ecological farming are, currently, about 60 to 70 per cent (and according to some studies up to 80 per cent) of those in conventional farming. Factors that reduce yields are the limited amount of easily accessible nitrogen in the soil when fertilizers are not used, and the necessity to include nitrogen fixing fodder crops in crop rotation. A factor that increase yields are that larger areas may be used for cereals when animal and crop production are integrated. In addition soil quality, e.g. humus content, will improve and compaction of soil diminishes when ley cultivation is introduced.

Given that today agricultural policy is to provide for self-sufficiency but not more, one may wonder whether it is feasible to supply the region with locally grown ecological food with only the currently available techniques and crop plants.

Several factors will influence the possible production capacity of ecological farming.

1) The area. In some countries in the region large areas that were used in farming a generation ago have been taken out of production. If these are taken back, there will be a 10 – 30 per cent increased agricultural area, at the expense of forest land.
2) Areas that cannot be used for cultivation may still be used for grazing animals, in particular sheep and cattle. These will also add to the diversity of the landscape both sceni-cally and biologically.
3) In the whole region, it is possible to increase the consumption of vegetables and other plant-based products in the average diet. However, given the role of animals in ecological farming as explained above, the changes would not be too drastic. They certainly imply a decrease in pork consumption. Today, pigs eat very much the same as humans. In part, this would be compensated for by a slight increase in poultry or perhaps cattle production. The total level of consumption of plant-based products would increase by around 50 kg/person/year, about half of which would be grains.

Taken together, all the factors suggest that it would be quite possible to support the population in the Baltic region by an entirely ecological agricultural regime.

6.6 The energy dilemma and net bio-production

Current ecological farming is every bit as dependent on the

Shadow areas and ecological footprints

The area used by man to provide the resources used, has increased through modern history in a dramatic way. In 'simple' largely pre-industrialized societies it is smaller, for example, about 0.4 ha/capita in India. In Europe it is much larger. In industrialized societies in western Europe it is some 3–4 ha per capita.

In many ways in the Baltic region, the area available is not enough to provide the ecological services used. On an average, we have access to 2.5 ha/cap (see table) of which 0.4 ha/capita is farmland and 1.0 ha/cap is forest. The area that a society appropriates for bio- production or as a sink, is the ecological footprints of that society. When the area 'at home' is less than what we use, we may say that we have 'colonized' an area outside where we live. Such 'colonized' areas are called shadow areas.

How large is the ecological footprint?

In a project at the Beijer Institute of Ecological Economics at the Swedish Academy of Sciences a rough calculation was made on the ecological footprints of the cities in the Baltic region, for several kinds of ecological services (Folke, C. et al 1995 and 1996). If these figures are averaged and used for the entire region we arrive at a first estimation of the ecological footprint of the population in the Baltic region.

When summing up the area used for the examined services and the area available for them, it turns out that they are approximately the same. If selected parts are studied, however, the conclusions are very different. This is true both for the sub-region studied and for the services studied; in particular for energy provision. For example, on an average, the 29 cities in the drainage area that have more than 250,000 inhabitants use resources that need an area of 600–1,000 times the area on which they are built.

Use of resources	***Used area ths km²***	***Available area ths km²***
Food		
Marine areas	1136	800
		Arable land
Paper and wood		
Forest land	53	836
Sinks for waste		
Phosphorus – arable land	97–255	353
Carbon – forest land	3025–7449	836
Nitrogen – wetland	379–1171	138
Total (ths km²)	1350–2741	2127
Total (ha/capita)	1.6–3.2	2.50

Food imports

When looking at specific items, again the picture changes. It is, for example, possible to calculate the area of orange or coffee plantation needed to provide every German with orange juice or every Finn with coffee. In fact Finland has the largest coffee consumption per capita in the world. It is also clear from the table that on an average we eat much more marine food than is produced in the region.

Energy imports

In the energy field, again the conclusions are very different. It is relatively easy to demonstrate how the Baltic region is not self-sufficient, even today with conventional farming, despite the fact that the per capita area under production is relatively large by global comparisons. Countries such as Sweden, Denmark and Finland currently import non-renewable resources which, when compared without quality corrections, contain more than twice the energy content of all the available net bio-production of the region. The situation is even more drastic for the highly fossil fuel dependent states such as Poland.

Let us look at the Swedish situation as an example. Imported fossil fuels are accounted for in the table above, only in respect of the area needed as a sink for the carbon dioxide produced. We may also ask how large an area is needed to produce the 230 TWh of imported fossil fuels, if we count on this as biomass.

The land equivalent of fossil energy

Forests produce some 500 m³/y/km² of wood annually which corresponds to 500x0.7=350 tonnes. When used for combustion this wood has a heat value of about 2,330 kWh/tonne. To produce 230 TWh we thus need 285,000 km² of forest, or 3.2 ha/cap.

Energy forests on arable land have a much larger yield, about 1,500 tonnes of wood/ha with less humidity and thus a higher caloric value, about 4,600 kWh/tonne. In this case, an area of some 34,000 km² would suffice. However, the access to this land for energy production will certainly be marginal in a future regime where energy imports are limited.

An alternative is to assume that the energy would be produced as rape seed oil. Fall rape seed yield is 1,200 l oil/ha and other species will give 800 l oil/ha per year. For 230 TWh of rape seed we will thus need 190,000 km², or 2.1 ha/cap.

Rape seed oil may be used as fuel directly but wood must be converted to, for example, methanol. The energy yield is then much lower, about one-third of what is given above, and the ecological footprint or shadow area will increase correspondingly. A further point is that Sweden also imports the uranium used in nuclear reactors, which produce some 67 TWh of electric energy, which is not included above.

When considering the factors mentioned, we may conclude that the ecological footprint and the shadow area are very much larger if energy production is included in the table above.

use of fossil fuels as conventional systems are. In a future ecologically adapted production, where resource management is priori-tized, energy efficiency will become a major factor. In fact, in this case, production aids that are currently not accepted in ecological farming would perhaps not be excluded entirely.

Agriculture does not use much energy compared to other sectors of society. In Sweden, for example, the energy utilization is some 7 TWh in the primary production out of a total of 470 TWh, i.e. 1.5 %. However industrial processing and distribution of food that follows take about 8 times that amount. The food itself has an energy content of some 9 TWh.

About half of the energy use is accounted for by diesel for tractors. Other major energy demands are drying grain for storage, from some 25 to 13–15 % humidity, production of chemical fertilizer (about 1 l diesel per kg of N) and electricity for various equipments for e.g. milling, warming etc.

In a long term sustainable regime different solutions to satisfy these energy needs will have to be developed. The solutions may include energy efficiency, the use of heat from animals and stables, use of solar panels, and biofermentation of manure to produce biogas. Fuel for machinery and tractors might be obtained as rape seed oil, ethanol from sugar or methanol from wood. In addition farm scale energy production from e.g. wind mills are interesting alternatives.

Surely, the concerns for the costs of ecological farming must be based on the real carrying capacity available, that is the net bio-production and its possible dispositions. It would be possible to produce some 3,5 tonnes of dry weight per ha yearly, with variations depending on location, crop etc. Food will, under these conditions, be of the highest priority, as will other fundamental requirements. Other, lesser, convenience and luxury items will come from the remainder of the net bio-production, from eventual hydro-power and from other renewable sources that can be used without disturbing the net bio-production.

The total pricing system for goods and services will need to be changed drastically and competitive pricing in the agricultural sector will be found among the ecological producers. Today's pricing system neither takes into account the finite nature of certain resources nor that production regularly causes costly side-effects on the ecosystem. It is thus not useful as a norm for the future and is not relevant as an indicator for just or unjust economic management.

6.7 A view on future agriculture

System ecologists, e.g. Odum, who calculate transformation efficien-cies between solar energy and certain energy carrier claim that 1 joule kinetic energy in wind consumes about 620 joule sun exergy, 1 joule geopotential exergy in rivers consumes about 23,600 joule and 1 joule unconsolidated organic matter about 4,400 joule. Can this be true? Take for example the geopoten-tial energy in a river into consideration. Water evaporates from sea and land by solar energy. It is transported by air movements generated by solar energy. It condenses and falls back to the ground. A small amount falls on positions from where some of it is let out to the river. The geopotential exergy that finally can be tapped depends on the supplied waters altitude above the level of the turbine.

Although the processes, mentioned above, are interconnected: the energy base in wind power, argued by for example Jackson (1992), to be 300–1,200 TWyear/year is, according to Odum, 7–28 times larger than what solar radiation can generate on earth. Leaving the accuracy in these figures out of consideration, they still give cause for dealing with the global energy management in a contextual way that includes the functions of the global ecosystem.

In a long-term perspective, resource use within the ecosystem's carrying capacity will require significant changes in our life-styles. Energy production alone will make this clear. Sweden can be used as an example. The total primary energy supply is about 470 TWh and the total net bio-production that can be collected is approximately 230 TWh/year. One-third of that is already used as an energy source for industrial processes and household heating. If the quality of these various types of energy source is taken into account, then the differences are much larger. The situation is similar in most of the western hemisphere, although the size of the discrepancy varies among the countries.

Even if we take into account other sustainable energy resources, such as hydropower, one can only speculate on what the result of long-term adaptation to a society with less than half the energy resources of today would be. Petrol-driven automotive traffic, diesel-driven motor vehicle traffic, and air traffic would have to be drastically reduced. Traditional energy uses such as household and office heating, including warm water would likely be compensated for by energy sources such as solar radiation or geothermal energy. Energy- and material-efficient systems of production will, no doubt, also be highlighted. This being the case, music, art and various forms education will probably be at an advantage, as life-quality components.

When the highly limited possibilities for long-distance transportation and the need for leakage-resistant bio-cycles are taken into account, a high degree of ruralization will most likely, be necessary. Further reasons for this would be increased needs for human labour in the primary production sector in the future and needs to tie the systems for social well-being to primary production instead.