Plant Nutrient Management, Livestock Density, Agricultural Structure and the Environment

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Plant Nutrients and Plant Nutrient Pathways

A Short Historical Outlook
In earlier days, when the majority of people were occupied in agriculture, plant nutrient resources remained largely within agriculture and were recycled. Plant nutrients in the form of manure from animal husbandry, household and slaughter waste etc. were returned to arable land. This made it possible to maintain the production level of the arable land but at a restricted level. At the same time, there was a shortage of plant nutrients which limited the production of food and thus the population. Not so seldom, people were starving.

At the beginning of the nineteenth century, the cultivation of clover in grasslands became common. Through its nitrogen fixing capacity, it could supply the pasture with nitrogen, which also could be used by the following crops. The farming systems that developed in the middle of the 19th century were to last about a century, until the end of the Second World War. Crop and animal production were tightly inter-connected in systems of production which were distinguished by fairly good biological balance. Different crops replaced each other at regular intervals in the crop rotation, where clover and other legumes provided a basis for nitrogen supply.

This development led to yield increases of more than 50% by the 1930s compared with the beginning of the 19th century. The insignificant use of fertilisers limited further increases in production and did not even compensate for the flux of plant nutrients in agricultural produce to cities and urban areas.

Figure 4.1. Nitrogen, phosphorus and potassium use. Averages for Sweden in kg per hectare arable land. (Claesson and Steinek, 1996).
At the end of World War II, the most dramatic and rapid change in our agricultural history occurred. The rise of a modern industrial society brought a rapidly increasing stream of people from rural to urban areas. This gigantic reallocation of people and the implemented methods of waste management led to plant nutrient losses, as the nutrients in waste were not recycled to arable land anymore. Instead inputs of mineral fertiliser, produced from cheap energy, became necessary. This, in combination with society’s demands for rationalisation and increased yields, led to the specialisation of agricultural production. The earlier balance between cattle, pastures and grain production was in large broken.

The plant nutrients in manure became unevenly distributed between different agricultural businesses. Intensive animal production gave a supply of plant nutrients in manure that was larger than arable soil and crop nutrient requirements. This led to negative effects on the environment, in the form of increasing leakage of nitrogen and phosphorus to the water and losses of nitrogen to the air. At the same time, pure plant husbandry farms had a lack of manure and consequently of plant nutrients that had to be replaced with mineral fertilisers. Manure was considered to be a waste instead of a resource!

A study of statistics on the use of manure and fertiliser during the years illustrates the change of use of plant nutrients in manure. Until the 1950s the use of mineral fertilisers was still very limited. In the 1960s and 70s, the agricultural extension service was still recommending that farmers consider manure a waste and instead use mineral fertilisers.

In the middle of the 1980s, a new awareness started to grow in Sweden on the importance of using the plant nutrients in manure as a resource for growing crops. Soil mapping regarding the amount of phosphorus and potassium was relatively common. Analysis of soil nitrogen content early in spring in order to predict the amount of nitrogen fertiliser needed started at the end of the 1980s and early 1990s. It was important to teach the farmers to once again first use the plant nutrients in manure in the best way possible and after that add mineral fertilisers to compensate for crop needs.

**Farm-gate Nutrient Balance**

In farm-gate plant nutrient balances the amounts of nitrogen, phosphorus and potassium accumulated on the farm are calculated and compared with the amounts that leave the farm. The usual nutrient inputs are: fertilisers, imported or purchased fodder, purchased animals, purchased seed, the deposition of nitrogen from the air and the amount of nitrogen fixed by leguminous bacteria. The
amounts of plant nutrients leaving the farm are usually contained in agricultural produce such as grain, milk, meat, potatoes, etc. but can also be in sold animals or gaseous losses of ammonia from fertilisers, manure or crop residues or leakage and surface run-off and denitrification. Manure, slurry, urine, as well as crop roots and harvest residues e.g. straw are usually only recycled on the farm and therefore are neither an input to the farm nor a product that leaves the farm and are not included in the farm-gate balance calculation. Special cases exist when manure is brought from one farm to another, where it is used as a fertiliser to crops, and in that case manure must also be considered to be an input of nutrients. The same thing applies when manure leaves one farm to be spread on another farm. In that case the manure must be considered to be a product leaving the farm and included in the farm-gate balance calculation. The same applies to straw if it leaves one farm to be used on another farm, when it must be included in the farm-gate nutrient balance.

To make the results of the farm-gate nutrient balance clear for implementation on the farm, the next step is to consider the results in comparison to the general status of the farm. Here comparisons are made to soil maps of phosphorus and potassium to see which fields are in the greatest need of nutrients. These are usually the fields farthest away from the barns and manure storage. Then a plant husbandry plan is elaborated where the results from the farm-gate balance are included when deciding which crops to grow on which fields, how to spread the manure/slurry/urine in suitable amounts considering the plant requirements, as well as the best timing and technology for spreading manure. Here consideration must be given to the crops, the soil type and risk for soil compaction and the weather. The next step is to add the fertilisers to the plan, to choose suitable fertilisers or combinations of fertilisers, suitable timing and technology for applying fertilisers and also to calculate appropriate amounts according to crop requirements and the soil maps and the previous crops and manure spread in earlier years.
Livestock Density

To ensure that manure is not produced in excess in comparison to the amount of arable land on the farm, it is important that there is a balance between the amount of animals on the farm and the amount of land available for spreading manure. The maximum number of animals has been specified with consideration given to the amount of phosphorus and nitrogen in manure and normal crop requirements and removal of plant nutrients. The limiting factor for Swedish legislation on livestock density is phosphorus, with a maximum amount of 22 kg phosphorus per hectare. As the amount of manure per area will be moderate, the risk of nutrient leaching of both nitrogen and phosphorus should be substantially smaller. It also means that it is possible to produce feed for the animals using the land on which manure is spread as a fertiliser. The nutrients only change phase from nutrients in crops as they pass through the animal intestine and become nutrients in manure to be used as a fertiliser for producing more feed. One other advantage with using phosphorus instead of nitrogen is that the figures on phosphorus content in manure are more reliable, as phosphorus losses in the animal house and during storage are almost non-existent.

In Sweden the main rule is that the supply of phosphorus from manure and organic fertilisers may not exceed 22 kg per hectare available land (with certain exceptions), counted as a five-year average. Until 31 December 2012, farms with livestock may spread the same amounts of manure as these livestock density regulations permit (See table 4.1). The supply of nitrogen via number of animals

Table 4.1. Livestock density in Sweden.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Animals/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td>1.6</td>
</tr>
<tr>
<td>Cows for breeding calves</td>
<td>2.3</td>
</tr>
<tr>
<td>Heifers, bulls, steers &gt; 1 year old</td>
<td>4.6</td>
</tr>
<tr>
<td>Calves &lt; 1 year old</td>
<td>5.8</td>
</tr>
<tr>
<td>Sheep and goats</td>
<td>15.0</td>
</tr>
<tr>
<td>Sows in production</td>
<td>2.2</td>
</tr>
<tr>
<td>Fattening pigs, places</td>
<td>10.5</td>
</tr>
<tr>
<td>Laying hens, places</td>
<td>100.0</td>
</tr>
<tr>
<td>Young hens, places</td>
<td>250.0</td>
</tr>
<tr>
<td>Broilers, places</td>
<td>470.0</td>
</tr>
<tr>
<td>Turkeys, ducks, geese, places</td>
<td>140.0</td>
</tr>
<tr>
<td>Horses</td>
<td>3.0</td>
</tr>
<tr>
<td>Mink, breeding females</td>
<td>50.0</td>
</tr>
</tbody>
</table>

Figure 4.4. Plant nutrient pathways on a farm.
Definitions and Prerequisites

per hectare may not be larger than what is shown in table 4.1.
Accessible land for spreading manure can consist of:

• Suitable arable land used for crop production on the farm.
• Arable land elsewhere if there is a contract on manure spreading for at least a 5-year period.
• Grazing land, pastures on farms with grazing livestock.

At most 50% of the area that grazing animals need for spreading livestock manure on can consist of pasture. Normally only 30% is used, as this corresponds to the livestock waste production during a 4-month grazing period. The animal density requirements apply to all farms with more than 10 animal units (1 animal unit: 1 cow, 3 sows, 10 fattening pigs, 100 poultry or 1 horse) in Sweden.

Agricultural Production Structure Sets the Framework for the Success of Measures on Farm Level

Progress towards sustainable agriculture has up to now mainly been characterised by agricultural adjustments in terms of ‘good agricultural practice’ at farm level. However, the results achieved have not reached the established goals, especially regarding nutrient losses. In spite of this fact, some improvements have been noticed.

Issues such as production levels, total input of nutrients in crop production, total numbers of animals and the degree of net export of agricultural products have to be further analysed with respect to sustainability concepts. Some fundamental prerequisites concerning the overall production structure of the farm sector have to be fulfilled if sustainability is to be improved through modifications of practices at farm level.

The distribution pattern of animal production very much sets the base level for nutrient losses to water, as well as to the atmosphere. High livestock density in relation to available land for spreading of manure often causes severe nitrate leaching and inefficient recycling of the phosphorus in manure. This is true on farms, as well as for regions. Animal production concentrated to certain regions creates heavy emissions and local negative impacts of ammonia per land unit.

Differences in environmental impact can also be identified in relation to the types of animals. Grazing animals such as cattle, horses and sheep provide opportunities to preserve old natural permanent grazing land and thus maintain biodiversity. The amount of permanent pastures is most likely one of the most important factors for biodiversity. The existence of grazing animals also has a positive effect on soil fertility, due to favourable crop rotations with a high proportion of perennial crops. Crop rotations with leys also require less pesticides than rotations consisting of annual crops only, which dominate on farms with pigs and poultry and on grain farms. However, animal products from ruminants cause greater losses of nutrients per unit produced than products based on pigs and poultry, due to the less concentrated feed and the use of roughage, which needs greater areas for production than grain feeds. This is one of the difficulties with measures that can be positive for one part of sustainability but negative for another.

Biodiversity, the characteristic of biological systems to be different from each other, is manifested at the level of genes, species, populations, communities and ecosystems. The main sources of threat are loss of landraces and old species, as well as destruction of habitats due to intensive, mechanical agriculture, land-use changes and abandonment of land, as well as polluting emissions. New niches for successor species can be created through adapted, extensive forms of land management, thus enhancing species diversity. Placing areas under protection within the framework of nature conservation treaties is an important but expensive instrument to preserve extensive areas as habitats and to protect the species that remain. Promotion of organic farming could also be a way to maintain biodiversity as no pesticides or artificial fertilisers are used.

Large farms are often regarded to be less favourable with respect to resource and environmental maintenance than small ones. Except for very large animal holdings, such a statement is not scientifically proven and good opportunities to afford better techniques for farm buildings, storage and spreading of manure on larger farms may even change the situation completely. It can be difficult for the farmer to check all the fields on a large farm and therefore the use of herbicides and pesticides can increase
Machinery pools can improve farm finances on all types of farms except the extremely large animal complexes existing today in the countries in transition, Poland, Russia, Belarus and Ukraine. Where there usually is no balance between the amount of animals and arable land for spreading of manure and a lack of techniques for correct manure storage and spreading.

**Organic farming**, meaning the use of no commercial fertilisers and pesticides, is in many aspects in agreement with the sustainability concept, but not in all aspects. Due to widespread growing of nitrogen fixing crops and use of organic wastes, nitrate leaching can often be unacceptably high, although often not as high as in conventional agriculture. As it is always more difficult to steer the mineralisation and uptake of organic nitrogen than compared to nitrogen in mineral fertilisers, this affects the problems with nitrate leaching negatively. Furthermore, continuous phosphorus export from the farm with agricultural products may lead to a phosphorus deficit in the soil, if not compensated for in some way. This could be the case even with respect to other nutrients depending on the soil type and origin. Compared with conventional agriculture, yields are usually lower in organic farming systems, which means that the production per hectare or production unit is usually smaller than for conventional agriculture. Organic farming with dual purpose milk/meat production seems to have the best market competitiveness in comparison with other types of commercial farming.

During previous decades, people were more closely integrated with agriculture and arable land. Animal feed was mainly produced on the farm and the amount of purchased necessities was small at that time. Today most people live in urban areas and the production of food relies heavily on purchases of necessities, including those from other countries. Transportation has thus increased to a large extent during the 20th century, as well as the environmental impact due to increased fossil fuel consumption and related pollution. Urban development and the increased dependency of farms on necessities from other countries has exaggerated the linear elemental flow. Nutrients, as well as non-biotic elements e.g. heavy metals and rest substances from pharmaceuticals accumulate in urban vicinities and on animal-dense farms and regions. Large distances between food producers and consumers not only create long transport of food but also constitute an obstacle for the recirculation of nutrients.

**Farming under less competitive conditions** is prevalent for holdings on less fertile land, mainly situated on the outskirts of agricultural plains and for enterprises situated far from urban districts. A lack of social infrastructure, e.g. availability of services such as education, health care, public transport and shops, may be a determining factor for the running of such farms. There usually also is a lack of complementary employment as well and it is common that the younger generation leaves the region to find opportunities in urban areas. Lack of competitiveness may also be a consequence of insufficient funds for investment in appropriate farm equipment or for purchases of essential means of production. When valuable areas are threatened, such holdings and regions may need special policy actions to survive. This applies to farming in Western countries and can be very important for farming in the Baltic States, Poland, Russia, Belarus and Ukraine.

**Conclusions for Sustainable Agricultural Structure**

**Integration**
- Crop and animal production should be more integrated in all countries.
- Very large non-sustainable animal holdings should reduce the number of livestock or be split up into smaller, more evenly distributed animal holdings.

**Biodiversity**
- The number of ruminants should locally correspond to the amount of old permanent grazing land to preserve biodiversity. In some countries it may not be possible to retain all such land, so selected valuable grazing areas may need special policies to maintain these.
- Remains of natural biotopes such as wetlands, islands in field etc. should preferably be saved.
- On-farm conservation of landraces and old species.

**Transport**
- Transport of feed, food and wastes should be minimized by promoting local alternatives before centralized ones when this is deemed profitable by life cycle analysis.
Definitions and Prerequisites

Less competitive farming
• All countries in the Baltic Sea Region should support remote and less market-competitive farming and the development of essential services and complementary employment, in order to preserve a viable countryside all around the Baltic Sea.

Co-operation within watersheds
• Co-operation between neighbouring farms should be promoted to overcome negative effects of extensive specialisation on individual farms by mutual care for the arable resources, such as permanent grazing land, exchange of feed and manure etc. This can be a way to achieve sustainability for the total area without jeopardising the benefits of specialisation of individual farms.

Organic farming
• Society should promote organic farming wherever it contributes to sustainable development.

Factors Regulating Nutrient Losses from Farms

Drainage and cultivation of wetlands and old grasslands may cause extensive nitrate leaching due to increased mineralisation of stored organic matter. Nutrient losses may also occur as a consequence of wind and water erosion, due to inappropriate soil management. In all other cases of unacceptable nutrient losses from arable land, the losses are related to the degree of fertiliser/nutrient input e.g. mineral fertilisers and manure. Heavy leaching of nitrogen can only occur in relation to intensive fertilization but not necessarily as a result of the fertiliser input in an individual year, but as a consequence of long-term use of high inputs. The purchase of feed and feed concentrates to the farm is often an underestimated or forgotten component of the farm nutrient balance. The ratio between total nutrient input and product output is a key factor directing the long-term losses. A goal should be to have as efficient use as possible of the nutrients on the farms, which should in many cases lead to reduced fertiliser input. This means that on livestock farms that the nutrients in manure should be used first before adding complementary mineral fertilisers.

As already mentioned, the use of animal manure in crop production is often a main contributor to nutrient losses to the atmosphere as well as to water. A lot of research has been performed with the aim of improving the utilisation of nutrients in manure but there is still more to be done in this field. If no other possible short-term measures are applicable to prevent excessive negative effects on the environment for regions and individual farms with an excessive production of manure compared with available spreading land, it could be of interest to develop methods to concentrate the valuable nutrients in manure through some sort of technical manure processing. That would make it possible to transport the nutrients in manure over greater distances, but at the same time these types of processes have a high energy input. Such research is underway and may provide one possible solution to leaching problems in animal-dense areas. This type of solution should only be used as an emergency measure during the time that it can take to implement other structural measures with a greater potential for long-term sustainability, such as adjustments of the livestock density.

Ammonia emissions are strongly correlated to the number of animals and also to the housing and ventilation system used, manure storage practices and spreading procedure. A less protein-rich animal feed diet decreases the amounts of ammonia in the manure that can be lost to the atmosphere. The same is true if the ventilation air is cleaned, the manure storage tank is covered and the manure is incorporated into the soil during or immediately after application. Efficient use of manure in crop production requires sufficient manure storage capacity in relation to optimal timing of spreading and suitable spreading technology as well as spreading amounts that are dimensioned according to the crops nutrients requirements.

Cropping practices such as soil tillage, choice of crop, crop rotation, timing and equipment for spreading manure are all factors influencing nutrient turnover and flow in the soil-crop system. In addition to more appropriate total fertiliser use, these are the main tools for minimizing the nutrient losses at farm level. Nutrient leaching and surface run-off may be reduced in systems with direct drilling, a high proportion of winter-green fields and manure spreading mainly during spring. Slurry seems to
give better opportunities for efficient handling and nutrient recycling than solid manure systems, due to recent developments in techniques. Slurry in Western countries commonly has a dry matter content of 5-10%. The slurry that commonly existed previously in countries in transition, Poland and Russia, with a dry matter content of approx. 0.5%, would lead to large problems as the amounts are so large that building suitable manure storage would be economically non-viable. Furthermore, problems with soil compaction are common when spreading large amounts of dilute slurry.

Point pollution sources of urine or leakage from manure storage are not acceptable in a sustainable production system. Furthermore, wastewater from households and farm buildings should be collected, stored and applied to farmland as a nutrient.

Conclusions for Sustainable Farm Management Concerning Nutrient Losses

**Nitrogen input**
- Application rates for nutrients should not exceed the crop nutrient requirements. National guidelines should be developed with fertilising recommendations and they should refer to:
  a) soil conditions, soil nutrient content, soil type and slope
  b) climatic conditions, precipitation and irrigation
  c) land use and agricultural practices, including crop rotation systems
  d) all external potential nutrient sources.
- Nitrogen nutrient balances should be performed on the farm to show the size of the nitrogen surplus and should be used when planning fertilisation.

**Phosphorus input**
- The available phosphorus content of arable topsoils should not exceed the requirements of acceptable crop production.
- The annual phosphorus input should be calculated in relation to:
  - the phosphorus content in the field
  - the crop requirements.
- Good monitoring data on the phosphorus status of arable land is needed in every country, as well as nutrient balances to show whether the supply of phosphorus in the soils is increasing or being depleted.
- At farm level the phosphorus input should be of the same size as the phosphorus removed. Phosphorus nutrient balances should be prepared for the farm to show the size of the phosphorus surplus and should be used when planning fertilisation.

**Livestock density and manure handling**
- In regions with high average livestock density, and preferably also on individual farms, the total number of animals should be reduced to a level consistent with efficient recycling of nitrogen and phosphorus.
- Efficient circulation of nutrients on animal farms in combination with a high degree of self-sufficiency in feed is a prerequisite for limited losses of plant nutrients.
- The utilisation efficiency of the nutrient content in animal manure should be improved as much as technically feasible. That can be achieved by:
  - building sufficient storage capacity for manure for optimal timing of spreading
  - covering slurry and urine stores to reduce the odour and the emissions of ammonia nitrogen
  - improving manure spreading techniques and maintenance of manure spreaders
  - incorporating slurry, urine and solid manure into the soil immediately after spreading on open soils to minimise ammonia nitrogen losses.

**Nutrient point sources**
- Nutrient point sources on the farm, such as from manure storage, milking parlours, silage storage etc., should be identified and eliminated.

**Crops and crop rotations**
- Choose crops and crop rotations with a minimum need for soil cultivation and keep a high proportion of arable land covered by crops during autumn and winter.
- In areas with more than 50% annual crops, the proportion of perennial crops or green cover crops should be increased. This is most urgent in areas with
Definitions and Prerequisites

sandy soils and in areas that are used for drinking water purposes and also on land sensitive to erosion.

New technology
• Promote the development and implementation of new technology that can reduce nutrient losses, such as precision farming with site-specific crop management by use of global positioning systems.

Criteria for surplus land
• The farmers should take environmental considerations into account when removing land from food production in a situation of surplus agricultural land for food production:
  - soils poor in phosphorus
  - organic soils on previously drained wetlands
  - soils sensitive to erosion
  - soils sensitive to nitrate leaching

Nutrient traps
• Create buffer zones and wetlands to reduce nutrient losses and increase biodiversity.

Additional Measures to Meet other Sustainability Issues

Soil fertility is determined by chemical, physical and biological soil conditions. Mineral fertilisers may be contaminated with pollutants due to the process by which they are manufactured, or depending on the origin of the raw materials. Phosphate fertilisers in particular display high levels of polluting elements, above all cadmium. Depending on the system of land use and fertilisation methods, these pollutants enter agricultural soils by fertilisers. Cadmium and chromium are the main contaminants, with lesser quantities of lead, nickel and arsenic being deposited. Recycling of urban waste may also contribute to the input of heavy metals, persistent toxic substances and rest substances from pharmaceuticals to arable land. However for most of the Baltic region, atmospheric deposition is the main pollutant source.

Soil erosion in the strictest sense refers to degradation processes exceeding natural dimensions. It is caused by water and wind and increased by intensive soil cultivation and bare soils. Soil erosion due to non-sustainable land management leads not only to loss of soil fertility, but also to water pollution through phosphates, plant protection products and nitrogen compounds deposited along with soil material.

Cropping methods in intensive farming, especially soil tillage and the use of heavy farming equipment, cause structural damage to both the topsoil and subsoil, especially compaction, with subsequent negative impacts on the regulatory functions and fertility of the soil. Structural damage leads to yield reductions. Topsoil compaction is repairable, but greater weights can lead to subsoil compaction, which is extremely serious, as subsoil compaction is irreparable. In recent years there has been a trend towards heavier farm machinery and at the same time better wheel equipment has become more common, but cannot always solve the problems caused by the large weights. Consideration must be given to total weight, wheel pressure and wheel equipment when developing or purchasing farm machinery for sustainable agriculture.

The inadequate use of plant protection products is always related to health and environmental risks. The utmost goal is to minimise those risks. To reach this goal it is necessary to improve the registration and handling and to reduce the overall use. Point-source pollution in connection with pesticides arises e.g. when filling or cleaning sprayers and with careless handling of plant protection products. Diffuse pollution is mainly associated with leaching or surface run-off, erosion or as wind-driven dispersal of pesticides. Pesticide residues are found in products as well as in water. On the other hand, the introduction of pesticides into crop production some decades ago led to a more reliable yield level and also to healthier harvests with respect to naturally produced toxins. In most countries work is currently taking place on minimizing the use of pesticides in agriculture and on replacing risky products with less toxic and easy degradable alternatives. Educating farmers in handling pesticides and requiring a certificate or license for all those handling pesticides and sprayers is important. The measures are well known and the work towards minimal or even zero-use has to continue. How close to zero we will come without jeopardizing essential benefits from proper pesticide use will be seen in the future.
The introduction of genetically modified organisms (GMO) is exponentially increasing in agriculture. Such new crops are often linked to the use of specific pesticides. Through gene insertion techniques, the crop can be made resistant to specific pesticides for combating weeds and fungi. Knowledge is still very restricted about the risks for genetic pollution of wild species but it now seems impossible to completely prohibit the introduction of these new seeds. In aquaculture, there is a risk of genetically modified material spreading to wild fish species. Use of GMO in animal husbandry is mainly a question of ethics. What can be done, and has to be done, is to adopt a restrictive policy for accepting and introducing GMO. At the same time, the use of GMO in crop production should not lead to an increased use of herbicides.

Intensive and increasing use of veterinary drugs e.g. use of antibiotics for animal medication and as growth promoters creates a serious human and animal health problem for the future. A number of bacteria have become increasingly resistant to antibiotics, restricting future possibilities of combating diseases. The use of antibiotics can be reduced if the breeding intensity, feed and housing conditions are suitable for the biological production potential of the individual species. Animal welfare concerns should be taken seriously.

An important step to achieve sustainability in agricultural production is to develop efficient recirculation of urban bio-waste/human effluents into cropping systems. For that purpose, appropriate waste collecting urban systems have to be established, where contamination with non-biotic pollutants can be avoided. The main purpose is to keep phosphorus in human food in circular flows in the soil-crop-consumer-soil system and also to stop urban pollution to water bodies. In many places the need for urban investment to enable the development of circular elemental flow will be enormous within the next few decades.

Fossil energy has to be successively replaced, due to the greenhouse effect and air pollution as well as the fact that it is a non-renewable resource. According to several sources, we have already passed peak oil. Agriculture can produce bio-energy. Some possible crops are willow (Salix), grass, oilseed rape and wheat. Among these, willow and grass seem to be the most favourable for the environment and also for soil fertility. Harvest residues such as straw can also be used for energy purposes. Consequently, using environmentally sensitive land for production of energy can improve the environment. To get the bio-energy sector to expand, bio-energy has to be efficiently and profitably produced and techniques for converting bioenergy to electricity and heat must be improved. Another way of producing energy that is becoming more and more interesting in the Baltic Sea region is through the production of bio-gas from e.g. manure and fermentation of some other waste products from agriculture. Production of renewable energy is usually area dependent and as such competes with food production.

The availability of clean groundwater is rapidly decreasing in most countries. Agriculture plays a role in this development, as nitrate and pesticide residues in water mainly originate from agriculture. Powerful measures have to be implemented if the present negative trends are to be broken and the remaining waters of high quality are to be preserved.

Agriculture produces nitrous oxides (N₂O), methane (CH₄), and carbon dioxide (CO₂) that are of substantial importance for the greenhouse effect with global warming as the ultimate result. These emissions are mainly attributable to livestock farming and combustion from heating and agricultural machinery. About three-quarters of the methane emissions from agriculture come from animal digestion. Agricultural machinery and mineral fertilisers account for about 60% of the fossil fuel consumption on cash crop farms. It has been calculated that the global emissions of greenhouse gases could be balanced if the soil organic matter content were to be increased by 0.01% per annum by implementing careful land use practices. This situation will not continue in the long run, but could be a solution during a transition period, while the emissions are measured.

Maintaining a high degree of employment is an essential component of a sustainable society. Employment is of fundamental importance to enhance social stability and personal finances and health. However, in the future it will most likely be difficult to sustain employment in most countries. In that perspective a general commitment for the agricultural sector, as for all sectors, should be to develop new profitable services and products based on farm assets and produce. This is really a challenge. In Sweden it has been calculated that employment in
Swedish agriculture will be reduced by approximately 40% up to 2021, mainly due to the implementation of more efficient production methods and increased yields in both crop and animal production.

In most countries farmers' income is often insufficient for necessary investments on the farm. Lack of time and income restrains farmers from finding and implementing new production methods. On the other hand, implementation of sustainable farming systems could in the short run lead to economic losses for farmers, in particular when the total output per land unit is reduced. To some extent, their income is linked to their degree of education. Extended education, demonstrations and advisory activities can no doubt improve farmers’ finances and their understanding of sustainable issues and willingness to change practices on the farm. Research and extension service can be of great importance not only for the financial outcome of the farm but also for the effects on the environment and for the sustainability of agriculture.

Conclusions on Additional Measures Towards Sustainability

**Finances**
• Farmers’ income should be sufficient to provide a fair standard of living and consist of reasonable compensation for products and other services.

**Water quality**
• Long-term water quality should be secured by suitable land use within potential and existing pumping areas for high quality groundwater. This usually corresponds to less intensive forms of land use.

**Soil fertility**
• Soil fertility should be maintained and improved with respect to soil organic matter, soil structure, nutrient status and contents of non-biotic elements and chemicals by use of only non-polluted means of production, non-compacting machinery and cultivation practices promoting increased soil organic matter.
• Nutrient balances, soil analysis and monitoring programmes should be established as a basis for appropriate use of arable land.

**Animal health and welfare**
• To promote animal health and welfare, animals should:
  - be fed a balanced diet
  - not be subjected to long distance transportation
  - preferably have outdoor access and be kept in loose housing systems.
• The use of antibiotics in animal medication should decrease and the use of growth promoters should be terminated.

**Genetically modified organisms, GMO**
• The introduction of GMO into food production should be subjected to a very restrictive approval procedure and any increase in the use of plant protection products should not be allowed.

**Bio-energy**
• Bio-energy production should be increased on excess arable land. Present land use must not jeopardise possibilities in the future to produce high quality food on the same land.

**Recirculation**
• The recirculation of nutrients and organic matter in urban bio-waste to the production of biomass on arable land should be promoted. Efficient administrative systems for waste quality assessment are necessary in every country.

**Plant protection products**
• The use and risks of plant production products must be reduced in the future. This can be achieved by:
  - selecting crops and cropping systems with less need for plant protection products
  - improving spraying techniques and maintenance of sprayers
  - making certificates obligatory after participation in courses on safe handling practices for all farmers handling plant protection products and sprayers
• All plant protection products must be registered and approved by national or international authorities.
Definitions and Prerequisites

Climate change
• Promote cropping systems that increase the soil organic matter content e.g. increase permanent grassland, perennial crops and reduced soil tillage.
• Promote farming with a reduced use of mineral fertilisers and imported feed.
• Introduce \( \text{CO}_2 \) energy taxes on non-renewable energy.
• Reduce ruminant livestock numbers and/or increase production level.

Employment
• Emphasise a sector commitment to developing new profitable services and products based on farm assets and production.

Expertise
• Implement action programmes for extended education, demonstrations and advisory activities for sustainable agriculture.
• Initiate and support research for sustainable agriculture and to mitigate and adapt to climate change.

Conclusions

For sustainable agriculture it is important to take into consideration the ecosystem concept and how all parts of the ecosystem are dependent on one another. Measures must be taken and plans made so that problems will not be created for the future. A holistic view on agriculture must be adopted. This means that it is important to use all nutrients such as those in manure as a resource in the most optimal way, but also that all inputs and resources should be used most effectively. Improved technology and combining the best from all farming systems is one of the keys. Consideration must be given to producing food and feed of high quality while minimising transport. The welfare and health of both man and beast should also be high on the agenda. Climate change must be combated and it will most likely lead to new crops, pests and diseases on plants, animals and humans, as well as a longer growing season. Good products should also lead to fair prices that make it possible to farm with a reasonable standard of living comparable to that in other parts of society. Here education and training, as well as the advisory service, will play an important role. Arable land will be become more and more important to feed the world population and produce renewable energy.
References


Chapter 4


Chapter 5