The environmental implications of high intensity livestock systems - identifying environmental indicators

C. Willeke-Wetstein
Department of Livestock Ecology, Justus-Liebig University, Ludwigstrasse 21, 35390, Giessen, Germany.

Summary

High intensity systems are defined as, industrial livestock production systems and intensive mixed crop livestock production systems with stocking rates over 1.5 livestock units per hectare.

The internationally accepted Driving Forces-State-Response Model of the OECD (1996) and the Environmental Risk Assessment used for local projects in Germany are used in the selection of indicators. Both models are presented and discussed in terms of their usefulness for assessing livestock production systems.

The choice of indicators depends upon the purpose for which they are to be used, i.e. whether the indicators are used for monitoring purposes or for the *ex ante* quantification of impacts. The applicability of several "driving forces" indicators is discussed. For instance, in the case of nitrogen, farm-gate balances are useful as rough *ex ante* estimates whereas within-farm nutrient cycles and individual animal balances require a much higher data input and may be used as monitoring instruments. Other issues for discussion are:

- NH_3 emissions
- Manure storage and application systems
- Fossil energy consumption
- Chemical use in feed etc.
- Feed and forage production.

Introduction

The main environmental impacts of livestock production are on soil, water, air, flora, fauna and non-renewable resources. Soil features are affected by nutrient contamination, trampling and subsequent erosion. Ground water is polluted with nitrates and pesticides whereas surface water is threatened by eutrophication. Toxic residues in food are a threat to human health and air pollution, with ammonia and other greenhouse gases, has a major impact on habitats and the world climate.

However, many of the complex relationships between livestock and environmental impact are not understood. Nevertheless political decisions are required in order to prevent irreversible changes occurring in natural resources. For this reason, a study co-ordinated by the World Bank, FAO and USAID was conducted with the aim of assessing current knowledge of livestock-environment interactions at a global scale (de Haan *et al*., 1997). Part of this study was aimed at selecting and defining useful indicators with which to describe these complex interactions (Willeke-Wetstein *et al*., 1997). This paper aims to do the same for high intensity livestock production systems at a European level.

Categorisation of livestock production systems

In order to make the definition of indicators easier livestock systems need to be structured. As part of the global study reported by de Haan *et al., 1997,* Sere and Steinfeld (1996) classified the world's livestock production systems into three broad groups, i.e. grazing, mixed farming and industrial systems. The land-based (grazing and mixed) systems were then further sub-divided according to agro-ecological conditions (arid, semi-arid, sub-humid, humid and temperate). The criteria upon which livestock production systems are classified into the three groups are presented in Table 1.

Table 1. **Classification of Livestock Production Systems (LPS) according to Sere and Steinfeld (1996)**

Characteristic	Industrial LPS	Mixed farming LPS	Grazing LPS
Dry matter fed	< 10 % farm produced	> 10 % originates from crop by-products	> 10 % of forage farm produced
Average annual stocking rates	> 10 LU per hectare		< 10 LU per hectare
Total value of production		> 10 % from non-live-stock activities	

Grazing livestock production systems are almost exclusively based on the use of native pasture. They account for 9% of the world's meat production (de Haan *et al*., 1997). Mixed systems are characterised by the integration of crop and livestock production. This is the largest category of production systems in the world. Mixed systems produce 92% of the world's milk and 60% of the pork. Industrial livestock production systems, as referred to in Table 1, are characterised by industrial production methods, small-scale urban or peri-urban units of production and are becoming increasingly important world-wide. In 1996 industrial livestock production, as defined by Sere and Steinfeld (1996), accounted for more than 50% of global pork and poultry meat (broiler) production.

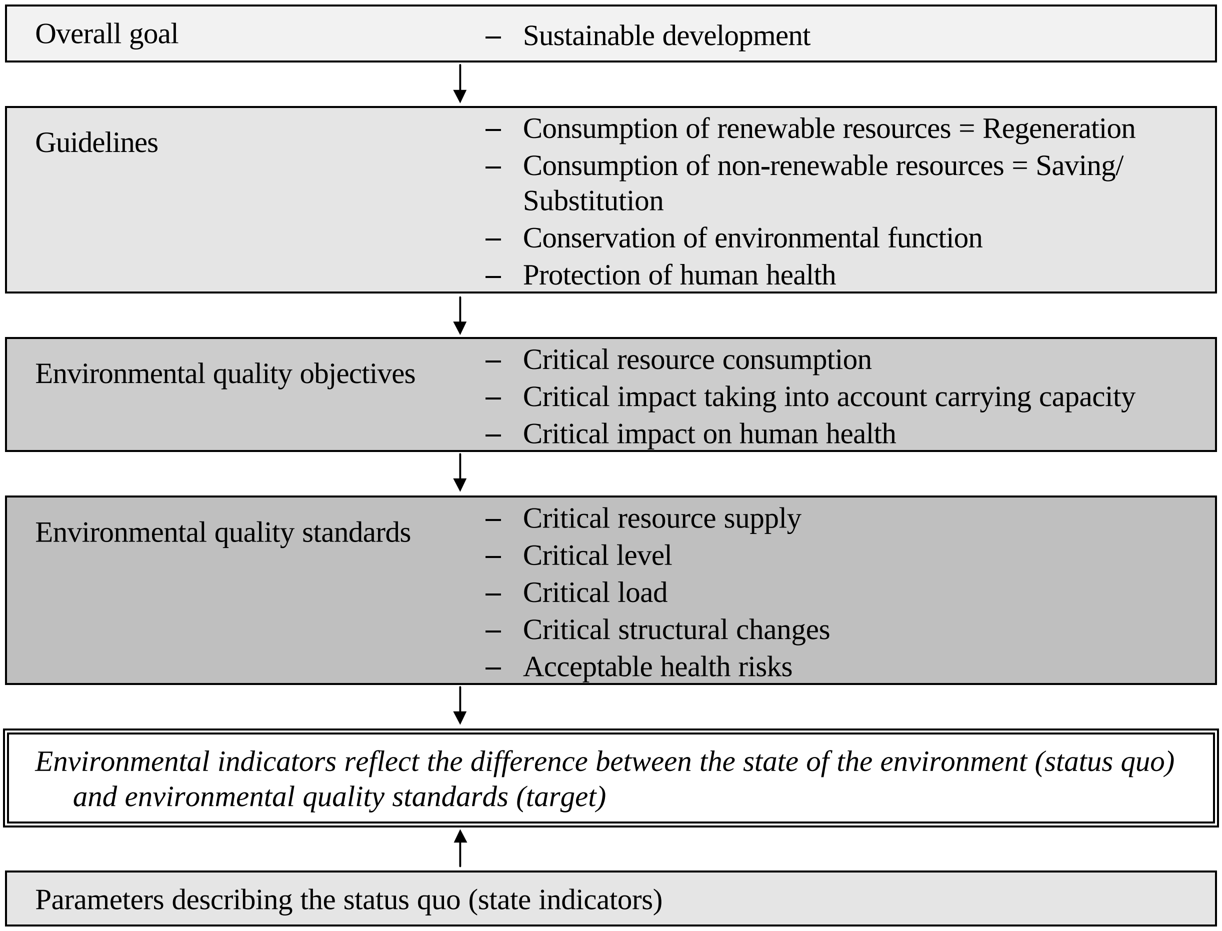
In the EU, mixed crop and livestock production systems with high stocking rates have similar characteristics to industrial livestock production systems. It is therefore proposed that European mixed systems be classified further into intensive and extensive systems using average annual stocking rate as one possible criteria for classification. In the following analysis mixed systems with a stocking rate of over 1.5 livestock units per hectare (where a livestock unit (LU) is equivalent to 500 kg live weight) and industrial systems fall within the same category of intensive livestock production systems.

Indicator models

Environmental indicators ideally reflect the difference between environmental status quo and environmental quality standards (SRU, 1994). This means that they are goal orientated with sustainability as the overall goal. Given sustainability as the overall goal, guidelines are formulated that take into account the precautionary principle. These guidelines in turn give rise to environmental quality objectives in the form of environmental quality standards such as threshold values and critical levels (Figure. 1).

Goal orientation is just one of the requirements that indicator models need to fulfil (SRU, 1994 and Bauer *et al.*, 1994). The main indicator requirements are listed in Table 2. In the light of this SRU (1994) evaluates a number of different indicator models. One of these models is the Pressure-State-Response model of the OECD (1993) later developed into the Driving Force-State-Response (DSR) framework (OECD 1996). The DSR model consists of three major components: Human activities, defined as livestock or crop agriculture and related processing activities, exert forces on the environment (nutrient deposition, energy consumption etc.), which change the quality and quantity of natural resources (soil, air, water, flora and fauna, and non-renewable resources). Society reacts to these changes according to the value it places on the natural resources, by implementing policies and regulations, which influence the driving forces.

Figure 1. **Goal-orientated development of environmental indicators**



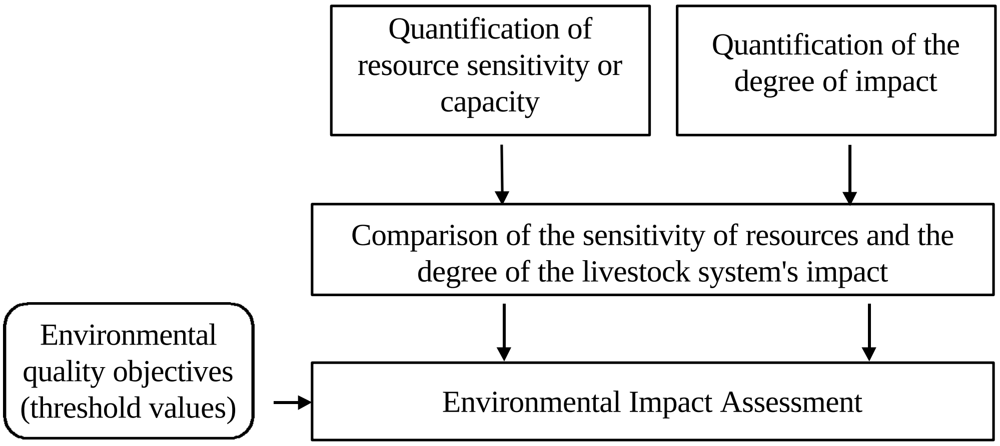
The DSR model does not meet all the above criteria. It is not goal orientated in terms of environmental quality objectives and, as such, does not take spatial or temporal limitations into account. Nevertheless, it is internationally accepted (de Haan *et al.*, 1997) and pragmatic with respect to political and economic requirements (SRU 1994, 1996).

Table 2. Basic indicator requirements

Practical Requirements	Easy to identify? National/international compatibility Does the indicator describe the object?
Scientific Requirements	Transparency Repeatability Is the aggregation comprehensible? Are the criteria for choice comprehensible?
Ecological Requirements	Is the risk of irreversibility covered? Does the indicator describe the potential (carrying capacity)? Are spatial and temporal limitations considered?

In order to compensate for the shortcomings of the DSR model, the principles of another assessment model used for projects at a local level will be incorporated into the structure of the DSR model. The Environmental Risk Assessment is the most appropriate assessment model for projects at a local level as it enables a comparison to be made between the project's impact and the sensitivity and capacity of the natural resource base (Bachhuber *et al.*, 1989). Environmental quality objectives serve as evaluation criteria (Figure 2.) and the transparent structure of the model gives the public insight into the decision-making process. It requires cause and effect models and therefore enables impacts other than those caused by livestock systems to be assessed. Environmental Risk Assessment calls for indicators that describe the status quo of the natural resource base on the one hand, and the degree of livestock impact on the other.

Figure 2. Environmental Risk Assessment Procedure (Bachhuber *et al.* 1989)



It is obvious that indicators have to be selected according to the subject of the assessment. The indicators needed to evaluate the impact a single livestock project are different to those needed to evaluate the environmental impact of national policy measures. Nevertheless final assessment depends on agreed environmental quality objectives. Quality standards and threshold values must be defined for each case. In order to follow the precautionary principle as defined in the European Regulation for Environmental Impact Assessment (85/337/EWG) scientific research should be the standard of comparison rather than existing legislation.

The SRU (1994, 1996) suggests that these standards should be set according to the concept of critical level, critical load and critical structural changes. This concept focuses on the effect of impacts and therefore considers multiple impacts. The concept was developed by the United Nations European Commission for Economy in order to set air pollution standards. The critical level describes the *concentration* of air pollutants whereas critical load is quantitatively expressed as the maximum level of *deposition* in the ecosystem below which no damage is expected. Short-term and long-term effects are considered as well as local differences. The SRU (1994) calls for critical loads not to exceed the carrying capacity of the most sensitive ecosystems.

With regard to landscape, natural habitats and vegetation, critical structural changes must be applied. Regional maps are required that demonstrate the status quo and reflect structural changes. It should be stressed that not only the area under consideration but also the way in which it inter-reacts with other areas is of major importance.

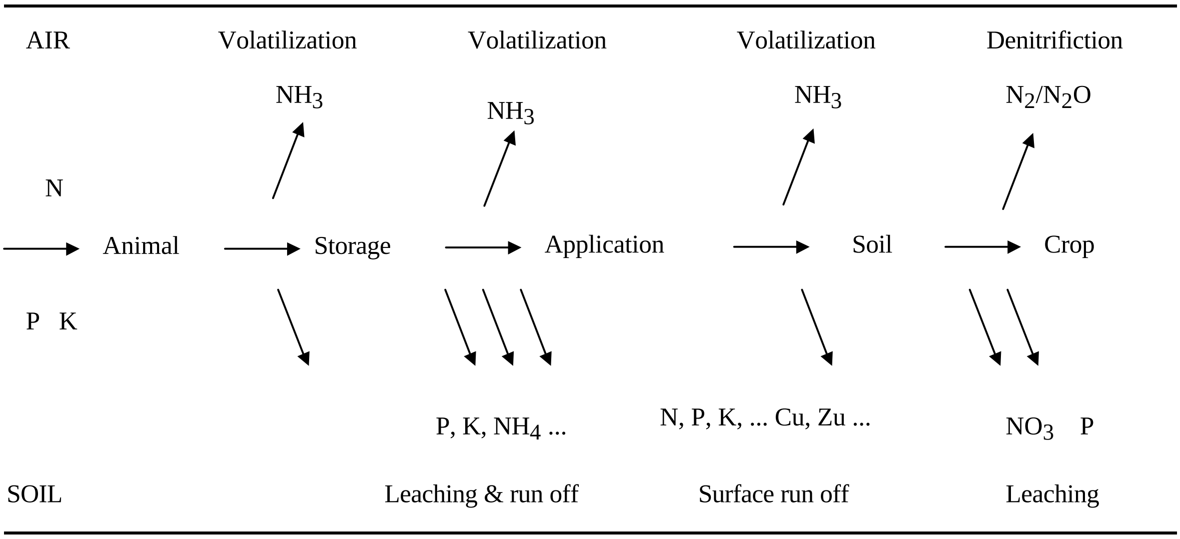
Farm level environmental indicators

Environmental impacts must be quantified at their place of origin, the farm. The farm types included within the description "high intensity systems" include intensive mixed and industrial livestock farms, i.e. dairy, veal and beef production units as well as pork and poultry (meat and egg) farms.

Nutrient emissions

Nutrient cycles are influenced by the inputs used on the farm, i.e. the feeding regime, including feed and forage production, manure storage and application. The nutrients concerned are nitrogen, phosphorus and potassium. They are emitted at different locations on the farm (Figure 3).

Figure 3. **Possible nutrient loss from manure between excretion and crop uptake**



Source: Bos and de Wit, 1996

Several European and national laws addressing the problem of nutrient surpluses have already been passed. These laws use the following indicators, which are used at the site of nutrient emission.

- Stocking rate expressed either in livestock units or manure equivalents
- NH_3 emission (The Netherlands)
- Manure application and storage techniques
- Mineral records and nutrient balances.

Stocking rate is a rather crude indicator and does not give enough information about nutrient cycles. As a driving-forces indicator it is, however, easy to obtain and can be used for the *ex ante* evaluation of farm projects. Together with information on production goals and feed management plans, rough estimates of the expected relationship between nutrient input and output and the emission of greenhouse gas can be derived from the stocking rate.

A better method for quantifying this nutrient question is, however, a nutrient balance. A number of computer farm models exist that calculate nutrient balances, but they have been mainly designed for plant production. However, REPRO, the model developed by Hülsbergen *et al.* (1997), calculates barn nutrient balances. Within this balance, two different parameters are calculated, the nitrogen in animal excreta and the nitrogen loss from livestock production. The latter includes losses from fodder storage as well as other nutrient losses, which occur in the barn (see Table 3.). The boundaries of a system may be defined according to animal type, animal husbandry system or the whole livestock enterprise of a farm. In addition Hülsbergen *et al.* (1997) define further environmental indicators which deal with the nutrient cycles. In total Hülsbergen *et al.* (1997) propose four principal indicators:

- N in animal excreta (kg N/LU), (optimum: < 120)
- N losses from livestock production (kg N/LU), (optimum: < 30)
- percentage of feed N in animal product (market product), (optimum: > 20)
- percentage of feed N and litter N in market product and manure (optimum: >80).

Optimum values (in brackets) are given for dairy farms in eastern Germany. REPRO looks at nutrient balances at every possible location within the farm system, including within farm nutrient cycles.

Another approach suggested by Eckert *et al.* (1997) is the so-called KUL *(Kritische Umweltbelastung Landwirtschaft* or critical impact of agriculture). The system boundary for KUL is the farm-gate, which means that within-farm nutrient transfers like nitrogen fixation in legumes are not taken into consideration. Eckert *et al.* (1997) argues that there is no data available on the average farm for working out anything other than the farm-gate balance. The KUL calculates the N balance, ammonia emissions, the P and the K balances**.** Eckert *et al.* (1997) defines optimum levels according to location. For instance, in the marginal area tested, the nitrogen balance at the farm-gate should not exceed 50 kg N / ha, whereas in the favourable area this is set at 30 kg / ha.

Schumacher (1996) calculates both within-farm and farm-gate balances for dairy farms in Hessian comparing conventional and organic farms. He also calculates nutrient balances for individual animals and herds using the feed programme and conversion equations produced by Kirchgessner *et al.* (1991a), which enable the nitrogen emission from dairy cows to be calculated. Schumacher (1996) demonstrated that there were large differences between individual farms, indicating a large potential for reducing nutrient surpluses.

Ammonia emissions are part of the total nitrogen emissions from livestock systems and are treated separately by many authors. Ammonia emissions occur during manure storage and its application to arableland and grassland. Ammonia emissions from animal housing and manure storage represent between 5 and 35 % of total N excreted, with a potential for reduction of about 50% for dairy cattle, pig and poultry buildings (Brandjes *et al*., 1996). A higher risk of volatilisation occurs after manure application. Marschner *et al*., (1995) measured ammonia emissions as percentages of NH_4-N after application to arable land and grassland, and found that the emissions from grassland were 1.5 times higher than from arable land. Injection of manure led to a reduction in NH_3 emissions of up to 90% compared to conventional distribution techniques. The dry matter content of the manure had the greatest influence on the amount of NH_3 lost (Marschner *et al.*, 1995).

Table 3. Results of nutrient balances for dairy farms in central Europe

Balance	Unit	Balance
Individual animal (Schumacher, 1996)	N output in kg N per cow per year (milk, meat, excreta)	N: 84 to 107 P: 13 to 17
Individual animal (Trunk, 1995)	N output in kg N per cow per year	N: 101 to 104
Barn (Hülsbergen *et al*., 1997)	N in excreta in kg N/LU	N: 90 to 124
	N losses in kg/LU	N: 24-38
Farmgate (Schumacher, 1996)	kg nutrient/ha	N: -10 to 83 P: -0.5 to 24
Farmgate (Eckert *et al*., 1997)	kg nutrient/ha	N: -39 to 22; P: -30 to 10
Within-farm (Schumacher, 1996)	kg nutrient/ha	N: 71 to 113 P: 1 to 22
Within-farm (Hülsbergen *et al*., 1997)	kg N/ha	N: -18 to 126

Eckert *et al*. (1997) derived the quantity of ammonia emissions from the farm-gate balance and set a critical limit of 50kg NH_3 per hectare. Trunk (1995) estimated 22 to 28 kg of NH_3-N emissions per livestock unit and about 5 g per kg of milk, with intensive farms producing more emissions per livestock unit.

To summarise, indicators of the nutrient cycle of farms comprise the balances given in Table 3 with additional information on manure storage and application needed in order to estimate ammonia emissions. For monitoring purposes, within-farm nutrient and individual animal balances should be calculated that allow for an increase in nutrient efficiency at different points in the production process. Stocking rates per hectare and per hectare of pasture as well as farm-gate balances and NH_3 emissions derived from estimates are useful for *ex ante* calculations. At a site of manure application state indicators for nutrients include, for example, the extent of natural ecosystems endangered by nutrient depositions (Table. 4). In order to define these areas, emission values at the farm level must be given in a compatible from (kg nutrient per hectare). Simultaneous consideration of the acidification and eutrophication effects of other polluters is also required.

Table 4. **Selected indicators for nutrient cycles (SRU 1994)**

Livestock indicators	– Farmgate balance – Within-farm nutrient balance – Barn nutrient balance – Individual animal balance – NH_3 emissions – (Manure storage and application system)
Overall emissions	– NO_x, NH_3, SO_2 emissions of all polluters – overall acid deposition potential – overall nitrogen deposition potential – overall phosphorus deposition potential
Place of Deposition	
Soil	– proportion of ecosystems endangered by acid and nitrogen deposition – proportion of soils endangered by P saturation – presentation of areas where critical loads are exceeded
Water	– proportion of ground and surface water and marine ecosystems endangered by eutrophication and acidification
Flora, fauna, habitat	– proportion of area endangered by eutrophication

Energy consumption

The energy consumption of livestock production systems is relevant because of (1) carbon dioxide emissions and (2) non-renewable resource consumption. Livestock production, characterised by high feed input and poor nutrient conversion efficiency, is less efficient in energy terms than plant production (de Haan *et al.*, 1997; Schumacher, 1996; Hülsbergen *et al.*, 1997; Eckert *et al.*, 1997). CO_2 emissions from agriculture do not in general contribute greatly to greenhouse gases. In Germany only 2.4 % of carbon dioxide emissions are the result of agricultural production (Trunk, 1995). However, high intensity livestock production has a higher energy input than extensive production. There are great differences in energy consumption between countries, livestock species and types of production system (Table 5). The process in livestock production requiring the most energy is, by far, the production of concentrate feed and its processing, whereas in plant production it is the use of mineral fertiliser, which is therefore also the relevant indicator.

Table 5. **The energy input into certain types of industrial meat production systems (in MJ per kg of live-weight)**

Component	Beef	Veal	Mutton
Energy input feed[1)]	11.5	41.7	14.0
Energy input animals[2)]	1.3	1.5	0.8
Energy input fattening (buildings, equipment, fuel and other)	2.7	3.6	4.5
Total energy input	15.5	46.8	19.3

[1)] includes fossil energy requirements for production, transport and processing of feed

[2)] fossil energy for the production of the animals

Source: Brand and Melman (1993), cit. in de Haan *et al*. (1997)

At the farm level, direct and indirect energy input is calculated, direct energy being the fossil energy used in the production process (diesel, electricity etc.) and indirect energy being energy used as an integral part of the production process (fertiliser, feed etc.). In order to make the calculation easier Eckert *et al*. (1997) did not consider the energy in investments such as buildings and machines. Energy balances are calculated per hectare, per livestock unit or per kg of live-weight. Schumacher (1996) compared the energy input on organic and conventional dairy farms in central Germany and found that the organic farms had a much lower mean consumption per hectare (Table. 6). The energy efficiency of organic dairy farms was demonstrated to be lower than that of conventional farms, but significant differences were not found. Energy balances have also been calculated by Hülsbergen *et al.*(1997) and Eckert *et al*. (1997). All authors report large differences between individual farms in the following indicators.

- fossil energy consumption
- energy efficiency (output/input ratio)
- energy intensity (MJ needed to produce one unit of grain equivalent, Hülsbergen *et al*., 1997)

Many questions regarding energy consumption, however, remain unanswered. It is difficult to compare the results of different authors as the way energy balances are calculated and the way system boundaries are defined is not always the same. To calculate the energy balance of a whole farm is costly, time-consuming and the results are only approximate. Nevertheless, for monitoring purposes it is recommended, given the large potential for reducing energy consumption. The energy balance worked out by Hülsbergen *et al*. (1997) and Schumacher (1996) including investments for housing and equipment is an example. It is recommended that for *ex ante* and policy evaluations the level of CO_2 emissions is estimated by taking the concentrate feed and mineral fertiliser inputs into feed and forage production as the main sources of CO_2. Feed rations can be analysed with regard to their CO_2 emission using the equation developed by Kirchgessner *et al*. (1991b).

Table 6. **Direct and indirect energy consumption in inputs on conventional and organic dairy farms (MJ/ha) (Schumacher 1996)**

Input factor	Conventional	Organic
Mineral fertiliser	6084	824
Purchased feed	5699	2473
Purchased livestock	353	21
Plant protection	306	1
Diesel	3971	4342
Electricity	3060	1519
Buildings	320	320
Equipment	1501	1501
Total	21,294	11,001

The relatively high energy input in intensive livestock production systems has given rise to a global goal of reducing the concentration of CO_2 in the atmosphere. This target implies that where an opportunity for reducing CO_2 emissions exists it should be exploited. Within livestock production there are three possible strategies for reducing CO_2 emissions:

- a decrease in energy input
- an increase in energy efficiency
- energy recycling through biogas production from manure.

According to de Haan *et al*. (1997) there is still a high potential for biogas production, particularly in high intensity systems, as biogas facilities are easier to use on large production units. The question, which research needs to answer is, does the production of biogas from animal manure compensate for the high energy inputs in intensive systems?

Heavy metals and veterinary medicines

Heavy metals like Cu, Zn and Cd are particularly important in high intensity systems since they enter the system in feed concentrates. Cu, Zn and Cd do not accumulate in animal tissues but in the soil and in particular where fertiliser use is heavy (Bos and de Wit, 1996; Brandjes *et al*., 1996). Levels of Cu in pig starter and fattening units in the EU have been reduced to 175 mg/kg and 35 mg/kg, respectively. In addition to a reduction in feed content, Brandjes *et al*. (1996) suggests that the use of P-equilibrium fertiliser (P in fertiliser equals P uptake by crop) might be a way to control the pollution of soil with heavy metals. However, in the Netherlands a five-fold surplus of Cu per hectare of maize was found under P-equilibrium conditions (high mineral and organic fertiliser supply). For monitoring purposes it is therefore suggested that the Cu and Zn content of manure in intensive pig and poultry systems be calculated. Cu is closely allied to P feed additives and can therefore be controlled by means of the P balance.

Little is known about the impact of feed additives and veterinary medicines. Antibiotic residues may occur in animal products, but the effects on pathogenic resistance in man are still unknown. Medicines used for livestock, and in particular those applied to whole herds, usually undergo a long process of tests and are not supposed to be used for human treatment. However, due to complex interactions between different environmental media and the synergistic effects in animals and man, negative impacts on humans can not be excluded. De

Wit *et al.* (1996) reported, that the resistance of pathogenic bacteria has not declined, despite the fact that only a few selected antibiotics are allowed for non-therapeutic use in livestock. The precautionary principle is highly desirable in this case. The same is true for the application of hormones and growth stimulants. As a result, both the use of hormones and the importation of meat produced using hormones as growth stimulants are banned in Europe. However, there is still no scientific justification for the ban on meat produced using hormones, although the World Trade Organisation has since requested one.

Given the large number of pharmaceutical substances found in feed additives and veterinary medicines, quantifying them at a farm level is both costly and time consuming. Feed additives are difficult to detect, as not all pharmaceutical substances must be declared by feed mills. For a declaration to be necessary it must be demonstrated that the pharmaceutical substance is found in the animal product and this means that a specific analytical method is necessary for each different substance. Existing national and European legislation regulates the use of pharmaceuticals and feed additives. However, it has been suggested that existing legislation should be constantly improved to take account of new scientific results and to increase the number of sample controls in slaughterhouses and on farms (see indicators in Table 8).

The best way of ensuring that livestock products are free from contamination is not to use pharmaceuticals on a large scale. High intensity livestock production systems and their concentration of livestock in large production units are at an increased risk from the spread of infectious diseases that need treatment with antibiotics. The risk of losing an entire herd as a result of these intensive production methods is also increasing. Consequently, there are two ways of ensuring food safety:

- a restriction on the number of livestock per unit.
- a ban on the prophylactic treatment of whole units.

Biodiversity

As mentioned in the section on indicator models, biodiversity of flora, fauna, and natural habitats as well as the impact of livestock on the soil through erosion can be directly quantified using indicators of critical structural change. These indicators must be quantified at farm level and expressed per hectare of farmland. Temporal factors also need to be included as does some specification of landscape structures (hedges, water habitats etc.) and the botanical composition of grassland. A regional approach is needed. However, using farm level data may also contribute to developing the more sophisticated data-bases required at regional and national levels, i.e.

- extent and inter-relationship of natural and semi-natural ecosystems
- percentage of landscape structures
- proportion and distribution of sealed areas (i.e. areas of soil at no risk from water penetration)
- proportion of area at risk from erosion

Environmental indicators at European and global levels

The environmental impacts of livestock production systems are not always confined to specific areas, but are of global concern. The following issues fall into this category:

- The production of concentrate feed

- The diversity of domestic animals
- Greenhouse gas production (CO_2, CH_4, N_2O)

The impact of processing livestock products is not discussed as this would exceed the scope of this paper.

The production of feed concentrate

Intensive livestock production systems use high inputs of concentrate feed. Industrial systems as defined by Sere and Steinfeld (1996), currently use 44% i.e. 500 million tons of the concentrate feed produced and this figure is increasing (de Haan *et al.*, 1997). However, it is difficult to quantify the exact impact of each tonne of concentrate feed imported by the farm. At a global level, concentrate feed production is an easily obtainable indicator to use. This is also true at a European Community level, where the corresponding indicator is the area used for concentrate feed production expressed as hectares of arable land (Table 8). Of interest are both the increase in the use of feed concentrate and where it is concentrated. A detailed map of concentrate feed production in Europe is needed in order, for example, to examine its impact on fragile ecosystems.

Diversity of domestic animals

Another impact of livestock production systems of global interest is on the diversity of domestic animals. Intensive systems require large numbers of high performance animals of consistent quality. Increasing demand for high performance breeds and intensive selection causes genetic erosion within these breeds to occur. As a result market forces have encouraged specialisation in Holstein cows. 60% of the dairy cattle population in Europe and 90% in the US is made up of Holstein cows. Table 7 shows that the majority of breeds at risk from genetic erosion are found in Europe and the Commonwealth of Independent States (CIS). Breeds at risk from genetic erosion are defined as those with less than 1000 female breeding animals and less than 20 males in existence and for which no conservation programme is in place.

Table 7. <u>Breeds of domestic animal at risk from genetic erosion by region</u>

Species	Breeds on file	Breeds with population data	At risk[1]	Projected at risk
Africa	396	239	27	27
Asia & Pacific	996	710	105	97
Europe & CIS	1688	1501	638	358
Latin America	220	143	29	27
Near East	378	214	15	9
North America	204	117	59	41
World	3882	2924	873	559

[1] At risk being defined as breeds where population data shows <1000 breeding females or <20 males and for which no conservation programme is in place.

Source: Hammond and Leitch (in press), cit. in de Haan *et al.*, 1997

Global objectives are needed in order to decide which breeds should be included in conservation programmes and which type of conservation programmes are appropriate. Once such goals have been set, Simon and Buchenauer (1993) suggest the following threshold values (quality standards) for observing the breed's state of genetic diversity:

- a 10 % decrease in female population
- a drop in herd numbers below 10 herds
- effective population numbers below 50
- matings with animals outside the population exceeding 10%.

In addition the breeding structure needs to be monitored with information on replacement rates, the ratio of males to females, age structure of the population, the extent to which artificial insemination is used and breeding patterns (hatcheries, breeding companies). For well-documented breeds all this data is available at a European level and should be used when deciding on what conservation programmes to implement, as suggested by Cunningham (1995).

Greenhouse gases

Greenhouse gases are produced directly by livestock populations as well as forage and feed production processes. Emissions of carbon dioxide, methane and nitrous oxide are all influenced in an indirect way by intensive production systems. Globally the main source of CO_2 emissions is the burning of biomass for livestock production (de Haan *et al.*, 1997). In Europe energy input for concentrate feed and forage production as well as housing systems all contribute to increasing the level of carbon dioxide emissions produced through burning fossil fuel. It has been shown that concentrate feed constitute the greatest energy input into intensive systems. Consequently, a possible farm or European level indicator could be the input of concentrate feed into the livestock production system. However, breaking concentrates feeds down further into by-products and food grains would be desirable.

Methane emissions are a result of human activities (rice cultivation, production and distribution of oil and gas etc.). Bouwman (1995) quantifies global methane emissions from livestock at 18%. The main source of methane is ruminants fed on low quality, fibrous diets. The characteristic diet in intensive production systems is high quality feed and therefore methane emission is not of major concern within these systems. However, Safely *et al.* (1992) estimates that 20% of livestock-related global methane emissions is caused by the anaerobic processes taking place in liquid manure. These processes take place in intensive housing systems with slatted floors. According to Bos and de Wit (1996) more than two thirds of pig and laying hen manure management systems are based on liquid manure. There is also the potential for biogas production, but so far this is not a significant problem.

To summarise, methane emissions should be seen in a global context and are therefore not an important issue for intensive livestock production systems. However, it is only possible to calculate the difference between current levels of CH_4 in the atmosphere and future CH_4 emissions by taking all methane sources into consideration. It is possible to make estimates at a farm level using equations developed by Kirchgessner *et al.* (1991b) for individual animals. Nitrous oxide emissions, N_2O, are likewise contributing to global warming. Less than one tenth of these emissions are produced by animal manure. At the farm level nitrous oxide emissions are included in nutrient balances. At a global level, the potential of polluters to contribute to global warming compared to critical concentrations in the atmosphere enables calculation of the critical load.

Environmental indicators for intensive livestock production systems

At an ecosystem level it is not sufficient to consider just the impact of livestock. This is particularly true when looking at nutrient cycling and acidification. Critical levels and critical loads are the environmental quality standards that have to be defined in consultation with other polluter groups and stakeholders in the natural resources. This is a political decision-making process that starts with the definition of state indicators which meet the indicator requirements listed above.

Software currently available facilitates the combination of emission-level and ecosystem-level data. However, the selection of indicators should not be restricted to available data-bases, instead the process of defining indicators should give rise to the collection of new data.

If environmental indicators for high intensity livestock production at a farm level (i.e. nutrient surplus, energy consumption, toxic substances and the biodiversity of flora, fauna and habitat) are to be useful to policy-makers, they must be selected bearing in mind their ultimate use as *ex ante* or monitoring indicators and should always be compatible with state indicators at regional, national or global levels.

A list of suggested "driving forces" indicators is given in Table 8. It is obvious, that the smallest unit, the farm, plays the most important role in terms of data collection irrespective of the spatial distribution of the impact. Additional information about the regional distribution and size of farms may also, at a later stage, facilitate the aggregation of data at regional, national, European and global levels.

Policy options and criteria by which they may be evaluated

Most of the indicators listed above require fairly intensive analysis at both farm, regional or ecosystem levels. Policy-makers do not have time to undertake intensive analysis and this is why they depend on readily available statistical data. This statistical data is usually economic data as this is relatively easy to compile. The OECD (1993, 1996) calls this the economic or societal response, which should be measured using response indicators that reflect (1) changes in the ecosystem and at the same time (2) the impact of environmental policies. Possible economic indicators are the current livestock production goal, the value of livestock production or profitability indicators such as the profitability of forage areas.

From these indicators policy measures, for example, to reduce the nutrient surpluses in livestock production, are derived. Possible policy measures listed by de Haan *et al.* (1997) for mixed livestock production systems are given below:

- taxation of inorganic fertiliser
- maximum limits on application and regulated times of application intended to reduce leaching and volatilisation
- taxation of feed imports
- incentives for the geographical distribution of crop and livestock activities.

Table 8. List of indicators relevant for intensive livestock production systems

Impact	Level of data collection	Indicators

Nutrient surplus	Farm	• Stocking rate • Farm-gate balance • Within-farm nutrient balance • Barn nutrient balance • Individual animal balance • NH_3 emissions • (Manure storage and application system)
Energy consumption	Farm	• Energy input (per ha, per LU, per kg live-weight) • Energy efficiency (output/input)
Heavy metal contamination	Farm, feed mill	• Cd, Cu and Zn addition to feed • P balance
Contamination with pharmaceuticals	Farm, feed mill, processing industry	• Pharmaceuticals in feed • Medicine residues in livestock products
Biodiversity	Farm, regional	• Extent and inter-relationship of habitats and landscape structures • Area at risk from erosion
Feed concentrate production	Farm, European, global	• Extent and distribution of concentrate feed production • Feed import (incl. share of food grain)
Diversity of domestic animals	Farm, European, global	• Size and distribution of herds • Structure of population • Breeding patterns
Greenhouse gases	Farm, European, global	• CH_4 emissions • Percentage of biogas production • CO_2 emissions from livestock • N_2O emissions

The choice between different policy options is made easier if an evaluation scheme as suggested by Willeke-Wetstein *et al*. (1997) is applied. An example for the policy measure of taxing feed imports is illustrated in Table 9. This model is applicable to any policy measure. The criteria may be ranked depending on the importance of the environmental impact. In the majority of cases a combination of different policy measures is to be recommended.

Table 9. **Evaluation scheme for environmental policies**

Criteria	Taxation on feed imports

Environmental effectiveness	
– Goal orientation	• high, 47 kg N/ha (41 %) and 22 kg P/ha (25 %) are imported (Isermann,1990)
– Space	• decentralisation of livestock production for Europe not expected
– Time effect	• immediate effect
– Environmental side effects	• not reported
Costs	
– Direct costs	• low
– Opportunity costs	• lower meat production expected
– Transaction costs	• high, due to possible reaction of GATT partners and costs of implementation at borders
System compatibility	
– Market orientation	• market regulation through price increase
– Individual freedom	• no effect
Administration/ bureaucratic aspects	• moderate administration input, no control within the country
Acceptability	• low due to price increases
Distributional effect	• capital intensive farms will still buy concentrates whereas capital extensive farms will be disadvantaged

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