Characterising high intensity livestock systems – identifying indicators of resource use, environmental impact and landscape quality

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Summary

The increased resource use and environmental impact of intensive livestock farming systems in Europe has lead to a demand for regulation. It has also lead to a demand for information on the actual impacts of different farming systems on values of interest to a wide range of stakeholders. There is no consensus on how the resource use and environmental impact of intensive farming should be described. This lack of consensus is the result of differences in the: types of environmental problems in different regions of Europe; different levels of focus (e.g. field, farm, water catchement area) and targets (use/user) for whom the description of the environmental consesequences of different farming systems is intended.

Thus, when defining indicators one should be very explicit regarding

- the normative assumptions made concerning how problematic issues, which are to be described by indicators, re defined,
- the stakeholders and interests behind the problems,
- for whom the indicators are meant and for what purpose (i.e. farmers, researchers or politicians),
- the level of detail that is appropriate for each target group,
- the possibility for acting on the basis of the information derived from the indicators (i.e. who can change the indicator values).

Although some attempts have been made to establish a set of key agri-environmental indicators, the suitability of different tpes of indicators for use at different levels of aggregation and across Europe needs to be further evaluated. The goal of this paper, is thus to:

- Argue why a set of indicators on farm level might be a good common reference for the development of indicators on more aggregated levels (regions, farm types etc),
- Give an example of a set of indicators selected to describe these aspects at farm level in a form suitable for appraisal by farmers and advisors as well as outsiders,
- Discuss different types of indicators that have been used for the environmental appraisal of livestock farms in Europe,
- Discuss the limits of the farm level approach and the potential advantages of a better co-ordinating farm level, regional level and EU level indicators of resource use and environmental impact.

The paper will both present and build on results from a project aimed at developing indicators of resource use and environmental impact on Danish livestock farms as part of a decision aid for

farmers. On the basis of these results the suitability of different types of indicators will be discussed. A set of indicators for high intentisty livestock farms will also be put forward. However, the variation between Danish livestock farms alone highlights the difficulties involved in the establishment of standard values for "typical livestock farming systems".

Introduction

The increased resource use and environmental impact of intensive livestock farming systems in Europe has lead to a demand for regulation. It has also lead to a demand for information on the actual impacts of different farming systems on values of interest to a wide range of stakeholders. Researchers have addressed these problems in different ways, ranging from conducting controlled experiments aimed at finding ways to improve resource use efficiency to quantifying nutrient flows and their aggregated impact at a national scale. At the same time increased regulation of the environmental aspects of agricultural production at both national as well as EU level has taken place. This regulation has, however, not always been based on the same type of information that experts have used to research and evaluate different agricultural systems.

There is no consensus on how the resource use and environmental impact of intensive farming should be described. This lack of consensus is the result of differences in the:

- type of environmental problem in different regions of Europe, i.e. loss of landscape values, pesticide pollution of drinking water, eutrophication of marine waters etc.
- level of focus, i.e. plot, field, farm, landscape/water catchment level etc.
- sources of available data, i.e. controlled experiments, continuous monitoring of private farms, farm accounts, national statistics etc.
- target use (/user) of the description, i.e. Public Regulation, dialogue between researchers, the advising of farmers etc.

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Although some attempts have been made to establish a set of key agri-environmental indicators (OECD, 1997), the suitability of different types of indicators for use at different levels of aggregation and across Europe needs to be further evaluated.

The goal of this paper, is thus to:

- Argue why a set of indicators at farm level might be a good common reference for the development of indicators at more aggregated levels (regions, farm types etc),
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- Discuss the different types of indicators that have been used for the environmental appraisal of livestock farms in Europe,
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Indicators of resource use and environmental impact in a farmer decision aid

The set of indicators presented here as describing resource use and potential environmental impact were developed for use in a new decision aid for livestock farmers entitled an ethical learning process. The idea of "ethical accounting for livestock farms" is to give information to the farm family on the impact of the farm on the interests of present and future generations, livestock animals and the farm family itself. The aim is to facilitate a reflection on the farming family's values and goals taking ethical aspects into consideration. If subsequently required, it should also facilitate a reflection on how farming practices can be adjusted to meet the family's values and goals. The term ethic in this context refers to the question of the right balance of conflicting interests, where the consequences of farming practices influence the quality of life for different parties (see Jensen and Sørensen, 1997 for the philosophical argumentation).

The selection of indicators for this ethical account was based on an analysis of the effects of Danish animal husbandry on the interests of future and present generations (Halberg *et al*. in preparation). These effects can be classified into the:

- use of non-renewable resources (fossil energy, phosphorus),
- impact on the farm's natural basis for production (the soil),
- impact on the surrounding environment, i.e. the conditions under (groundwater), over (atmosphere) and around (marine environment, wildlife) the farm.

Table 1 gives an overview of the indicators included and describes their rationale, resource use and potential environmental impact.

The loss of nitrogen (N) from livestock farms may contribute to an increase in the nitrate content of ground water used for drinking water or the eutrophication of marine waters thus reducing the water's biodiversity and the amount of consumable fish (Christensen *et al.*, 1993). Phosphorus (P) is not presently leached in significant amounts in Denmark but in some regions of Europe this is considered an important problem (van Riemsdijk *et al*., 1987). Phosphorus can also be lost via surface erosion into streams and lakes where it causes eutrophication (Schjønning *et al*., 1995). Sources of mineral P are limited (Tiessen, 1995), which is why its present overuse in European farming (Sibbesen and Runge-Metzger, 1995) may have serious consequences for future generations.

Table 1. **Defining a livestock farm's resource use and potential impact on the environment**

Topic	*Reason, Localisation of Potential Impact*	*Indicator*
Area	Limited resource	ha
Nitrogen (N)	Pollution of the ground water, eutrophication of marine waters	Surplus, kg N per ha N-efficiency (kg N sold in products per kg N net input)
Phosphorus (P)	Limited resource, long-term pollution risk	Consumption, kg P per ha Surplus, kg per ha, P- efficiency
Energy	Limited resource Pollution CO_2 etc.	MJ per ha MJ per kg milk or meat MJ per kg grain
Pesticides	Pollution of ground water Wild flora and fauna	Treatment frequency index % unsprayed area
Windbreaks, small biotopes, meadows, streams	Wild flora and fauna Landscape aesthetics	% weeds in grain crops % uncultivated area
Soil	Pollution Soil structure Soil fertility, Erosion	Zn and Cu surplus, kg per ha (pig farms) Number of ha run over with axle loads >10 t (not determined)

The annual farm-level N surplus represents potential losses in the forms of ammonia or nitrous oxide volatilisation and nitrate leaching. Although the actual loss in any given year might differ from this surplus, principally as a result of changes in the N content of the soil, in the long run the N surplus will reflect losses as N mineralisation increases with an increase in the N content of the soil (see Halberg *et al*, 1995 for references). The surplus and efficiency of N and P are calculated at a farm level and at herd and crop/field levels according to Halberg *et al*. (1995). Farm-level figures include nitrogen fixation estimates and show the effects of the interdependencies which exist between the crop and livestock enterprises of any given system.

The use of fossil energy is of interest because it is a non-renewable resource and because burning it contributes to global warming. The indicator chosen includes both direct (diesel and electricity) and indirect energy (e.g. energy used for the manufacturing of fertilizer, feed concentrates and machinery) and is calculated using the methodology developed by Refsgaard *et al*. (1997). The diesel and electricity used on a farm is distributed to different enterprises on that farm according to the field operations and feeding systems in use (Fluck and Baird, 1980). The resulting energy price is expressed as MJ per kg milk (and per kg grain or cash crop) delivered.

Pesticides may have a negative impact on those who apply them as well as, unintentionally, on other humans or land organisms (e.g. beneficial insects). Pesticide use is also of interest for future generations as there is a risk that the flora and fauna in uncultivated areas might be damaged as a result of pesticides or their breakdown products being carried in the wind into hedges and streams (reducing biodiversity) or leaching into the ground water, where water reservoirs may be contaminated and habitat's destroyed. To account for the pesticide use on a particular farm the average number of standard treatments over all crops is calculated (Treatment Frequency Index, TFI).

The current impact on soil quality is of great interest for future generations. Farming may enhance or reduce soil fertility, improve or damage soil-structure and may cause the loss of topsoil by erosion or poisoning, for example, with heavy metals. However, soil quality is a multidimensional concept dependent upon the interaction of physical, chemical and biological factors and there is no consensus on which are the right indicators of soil quality (Karlen, 1990; Doran and Parkin, 1994). Given that there are several ongoing projects researching indicators of soil fertility and most of the measurements proposed so far are costly, no indicator for the status of soil fertility was included in the prototype of the ethical accounting system for livestock farms. An indicator describing the risk of long term damage to soil structure below the ploughing layer due to vehicles with high axle loads (Håkonsson and Reeder, 1994) was included in the third year. On pig-farms the surplus of Cu and Zn was also calculated, as there is a risk that these heavy metals may become concentrated in the soil with possible detrimental effects on soil organisms (Bååth, 1989; Huysman *et al*. 1994) and animals (especially sheep) grazing on the soil in the future.

With 2/3 of land used for agriculture, the wild flora and fauna in Denmark is very dependent on farming practices as well as on the extent and quality of the small uncultivated biotopes between fields (McLaughlin and Mineau, 1995; Prip *et al*., 1995). The percentage of weeds left in grain crops after heading is important not only for the population of weed species but also for the number and biodiversity of insects and birds (Reddersen, 1997). The percentage of small biotopes (small uncultivated areas between fields including hedges and streams) is interesting because they contribute to biodiversity and to landscape aesthetics. The connectivity of the biotopes is considered to enhance migration and the genetic renewal of species (Forman, 1995) and is presented visually in the ethical accounts.

Variation in indicator values between 20 Danish livestock farms

The ethical account was developed in cooperation with 20 private livestock farms and indicator values were calculated as part of the annual farm accounts between 1 May 1994 and 31 April 1997. Tables 2 and 3 shows selected results and the variation between farms.

The variation in N-surplus was largely due to a combination of management and stocking rate. Comparative data from other intensive livestock farms in Europe shows even larger variation due to differences in fertiliser rates, feeding strategies and stocking rates (Doluschitz *et al*., 1992; Korevaar, 1992; Halberg *et al*. ,1995; van der Ploeg, 1996).

Table 2. <u>Selected indicators and examples from the ethical accounts of fifteen dairy farms 1995-96</u>

15 Dairy Farms *					
			Average	**Minimum**	**Maximum**
Number of farm	**8**	**13**			
Farm size (ha)	155	107	92	50	155
Number of cows / farm	141	91**	75	38	141
Energy use (MJ per kg of milk)	2.3	3.5	3.0	2.1	3.9
N-surplus (kg per ha)	103	204	132	58	272
P-surplus (kg per ha)	5	19	11	0	28
Average number of standard pesticide treatments	0	0.8	0.5	0.0	3
Pesticides (% of untreated area)	100	48	78	24	100
% weeds in small grain	18	1	4	0	17.5
% small biotopes	4	5	4	0	9.5

*10 organic and 5 conventional
**Plus 1874 pigs per year

The use of energy per kg milk on dairy farms (Table 2) varied between 2.1 and 3.9 MJ, the highest values being on the conventional farms using high levels of fertiliser and concentrates and the organic farms using dried grass pellets in the feeding ration. Unsurprisingly the energy use per kg milk was higher on farms with irrigation (Refsgaard *et al.,* 1997).

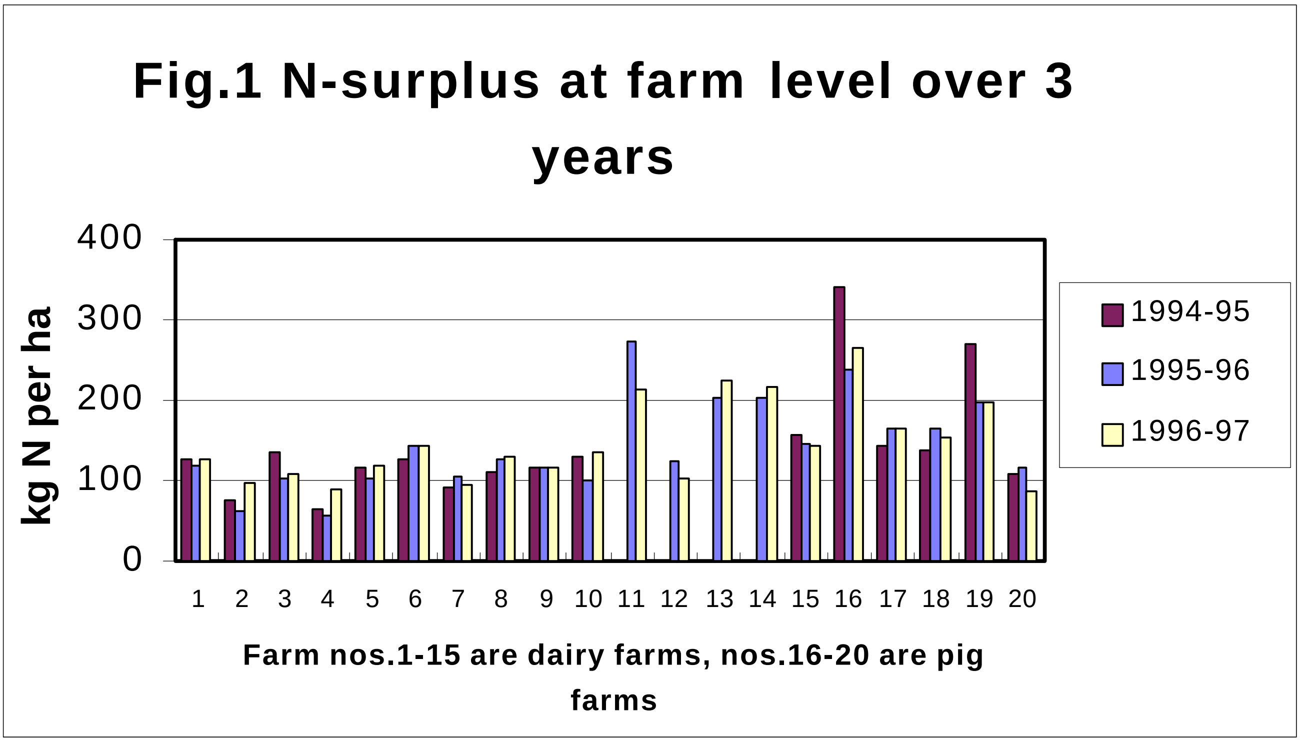
The large variation in the percentage of weeds left in grain crops was a combined result of the difficulties of mechanical weed control and the differences in soil type and crop competition on the organic farms. On the conventional farms no weeds were visible at the point of grain emergence except in crops under-sown with grass-clover.

The area of land left uncultivated (small biotopes) varied between 0 and 19% (Tables 2 and 3) as a result of a combination of differences in farmers' attitudes towards game and aesthetics and differences in the soil and landscape characteristics in different parts of the country. Some farms had established several windbreaks, while others were at no risk from wind-induced soil erosion. It was surprising that two of the organic farms had virtually no uncultivated biotopes, despite the organic movement's goal of furthering natural and wildlife values.

The surplus of Cu varied between 0.1 and 0.7 kg per ha between the five pig farms (Table 3) due to differences in the amount of Cu used as a growth promoter. With a natural content of roughly 35 kg/ha in many Danish soils, there is a risk that the Cu content on some farms might be doubled within a generation, making Cu contamination the single most severe problem of heavy metal pollution facing Danish soils (Larsen *et al*., 1996).

Table 3. **Selected indicators and examples from the ethical accounts of five pig farms (1995-96)**

Farm number	16	17	18	19	20
Farm size (ha)	38	180	112	77	215
Livestock units per hectare	3.1	0.5	2.5	2.4	0.6
Energy use (MJ per kg live weight pig)	10	20	15	18	16
Energy use (MJ per kg grain)	77	170	130	165	145
N-surplus (kg per ha)	238	164	165	198	117
P-surplus (kg per ha)	22	23	11	29	10
Cu-surplus (kg per ha)	0.7	0.4	0.2	1	0.1
Pesticides (Treatment Frequency Index)	0.53	2.5	1.37	1.48	2.56
Pesticides (% untreated area)	17	13	0	18	0
% weeds in small grain	2	1	0	1	0
% small biotopes	8	14	2.8	19	4.1
Farms no. 16-19 have sows, farms no. 17-20 produce hogs					



The variation between farms was generally greater than the variation between years on the same farm. Most of the differences between years on the same farm could be explained by changes in management practice. As an example, Figure 1 shows the farm-level nitrogen surplus per ha for three years on all 20 farms. Farm no. 11 had a significantly higher N-surplus in the year 1995-96 than farms no. 13 and 14, although all had comparable stocking rates (1.1, 1.3 and 1.3 Livestock units per ha respectively). This is the combined result of a crop rotation dominated by grass-clover and a mixture of barley and peas grown for whole crop silage (high biological N-fixation) and a consequently high-protein diet for the cows. The other two farms used fodder beet and a more balanced feed ration. In 1996-97 the N-surplus on farm no. 11 was reduced, primarily due to a reduced input of fertiliser and lower level of N-fixation in the barley/peas mixture caused by the failure of the pea crop to become established (only 7% ground cover in June 1996 compared with 52% in 1995).

Different types of indicators for environmental appraisal on livestock farms.

Only a few attempts have been made to develop a broad set of environmental indicators for appraising European livestock farms and most of these have been qualitative, such as in Nocquet (1995). Recent European work on the establishment of principles for the appraisal of sustainability has focused on arable farming systems (LEAF, 1993; Girardin and Bockstaller, 1994; Vereijken, 1994). Livestock farms are more complicated to describe because of the interdependencies between livestock and crops (for example, nutrient efficiency and energy use). The possible conflict between animal welfare and environmental goals (for example, nutrients may be more easily lost from outdoor pig systems or cattle on deep litter straw than from slurry-based housing systems) also means that an aggregated farm level description makes more sense. Table 4 presents the different types of indicators used in the literature, although no attempt has been made to give a complete review of all approaches here.

Table 4. **<u>Different types of indicators with examples from agricultural environmental accounts (EA: Ethical Accounting (see Table 1))</u>**

	State indicators	**Control indicators**
Qualitative	Use of manure problematic (Nocquet, 1995) Soil quality: very healthy – very unhealthy (Garlynd *et al.*,1992)	Manure planning practised (Nocquet, 1995) Plan for landscape and wild life -yes/no? (LEAF 1993)
Quantitative - absolute values	N-surplus, kg N per ha (EA) % nature habitats (Vereijken, 1994)	X% area run over with axle loads >10 t (EA)
- efficiencies	Energy efficiency (EA) N, P efficiency (EA)	
- index numbers (p = number of points * = multiply)	Pesticide index (Vereijken, 1994) 2 points for supplying wheat < 50 N; 2 pesticide-appl.: 0.6*p (Mayrhofer and Schawerda, 1991)	Crop rotation preventing plant diseases (0-10 p) (Girardin and Bochsteller, 1994) Soil cover index (Vereijken, 1994)

The aim here is to demonstrate that there is a difference between control indicators, describing the farmer's operations on the farm (i.e. actions that are expected to influence a later result), and state indicators, describing an accumulated result over a specific period (the N surplus of a farm is the combined effect of all actions which influence the farm's N-turnover, including the import and export of products, choice of crop rotation and fodder rations for the herd)[1]. There is often a cause and effect relationship between a certain control variable and a state variable. For instance, the introduction of a manure plan (control indicator/variable) might reduce the nitrogen surplus (state indicator/variable) and the prevention of disease through crop rotation might be expected to reduce the average number of pesticide applications. However, what is conceived to be a state variable at a farm level will often be a control variable at another level (e.g. landscape, region or sector level), as discussed below.

Another distinction between qualitative and quantitative indicators (Table 3), is that qualitative indicators facilitate a faster appraisal than quantitative ones, but are less precise and more difficult to compare across years or farms. Quantitative indicators may be subdivided into absolute values, efficiencies and different types of index values as illustrated by the examples in Table 3. Efficiency illustrates, for example, how much of a particular input appears in the final products (N-efficiency) or how much of a particular input is used per unit produced (MJ per kg milk). An index relates the amount of an input to standards (PI is the amount of pesticides used divided by standard doses; see Vereijken, 1994 for details) or places the farm's result on a scale (biodiversity between 0-10, Girardin and Bockstaller, 1994).

The calculation of indexes almost always involves value judgement, i.e. what are standard values, how many points should a certain result represent etc.? As qualitative or index indicators relate directly to a scale, it can be assumed that they are easier for farmers and consumers to interpret. However, they are the result of value-based assumptions on how an absolute value should be translated into values in an index and on assumptions about extremes. Once these assumptions have been made clear, the difference between how easily absolute values and indexes are interpreted may not be so important. Results presented as index values on a closed scale (for example, crop rotation and other indicators valued between 0-10) give a rapid overview of the farm's position in relation to extremes.

Where possible, quantitative state indicators have been chosen for the ethical account as these best facilitate combination with traditional technical economical indicators, the evaluation of changes over time on a given farm and comparison with similar farms or official target values. An exception to this is the lack of a state indicator for soil fertility as discussed above. A discussion of the demands on and the feasibility of the indicators in the ethical account as seen from the farm managers point of view is given in Halberg (1997) and Halberg (1998). In the following section the suitability of farm level indicators for use at a political level will be discussed. Issues lacking indicators will also be identified.

From farmer decision aid to policy-making decision aid

When defining indicators and the level at which they should operate, the farm is of key importance as:

- any changes in the effect of farming on the environment are the direct result of changes in individual farmers' management practices (except for the loss of certain farms),

[1] As inspired by Harrington (1992) and OECD (1997).

- most farmers adjust their production methods and land use patterns in accordance with values and goals which concern the whole farm (Nitsch, 1990; Bawden, 1992; van der Ploeg, 1993; Noe, 1995).

However, the need to generalise to a certain extent at levels appropriate for policy-making does mean that it is important to define indicators, capable of describing the environmental impact of farming at an aggregated level. How the indicators presented above correspond to or can be used directly in appraisals at a regional or other even more aggregate level, will be discussed in the following paragraphs.

The feasibility of using farm-level indicators at the level of aggregation needed in policy-making

In order to be useful in political decision making (at local, national or international levels) indicators of the resource use and potential environmental impact of agriculture must be defined at an appropriate level for comparison against environmental targets.

Farm-level surpluses of N and P, calculated on a per hectare basis, correspond to goals and targets formulated at a national level, for example, the Danish and Dutch targets for reducing N loss from agriculture to specific quantities per year. In the Netherlands this has been followed by the establishment of an obligatory farm nutrient accounting system.

This system appears to have advantages over the EU's Nitrate Directive and Danish laws, which regulate the use of animal manure on the basis of different standards for different types of livestock, barn types and crops. When regulation is based on guidelines for good agricultural practice building on the traditional concepts of the partial economic optimisation of nutrient use in different enterprises, a coherent evaluation of the farm’s actual nutrient loss is lacking (Halberg *et al*., 1995; Halberg and Jensen, 1996). This makes evaluating the results of regulation and the need for stronger measures unnecessarily difficult. In addition, important information found in the large variation between farms all following the same rules is lost (as illustrated by the variation between the 20 farms above).

The model of fossil energy use used here, works equally well at several different levels of aggregation and corresponds to sector level analyses of energy use in agriculture (see for example Pimentel *et al*., 1973; Schroll, 1994). Depending on the ultimate purpose of the analysis, an appropriate indicator might be the total fossil energy used (direct and indirect) of a sector, the input-output ratio (MJ used per MJ of energy in the products) or the energy used per unit of product. If the aim is to evaluate the energy efficiency of, for instance, different pig production systems and their potential for improvement the latter seems the most appropriate (i.e. MJ per kg meat).

The number of standard pesticide treatments (Treatment Frequency Index, TFI) for different crops in Denmark is calculated annually at a national level by Miljøstyrelsen. The official target for reducing pesticide use was formulated in both kg of active ingredients and in terms of the average TFI for all crops. This indicator is thus applicable at crop and farm as well as more aggregated levels. A similar indicator was agreed by researchers from different EU countries (Vereijken, 1994). However, the problem is that this indicator does not distinguish the pesticides used by their level of toxicity or risk of leaching or volatilisation. Secher and Gyldenkærne (1996) and Wijnands (1997) have proposed methods for the environmental ranking or grouping of pesticides on the basis of both their volatility and their LD50 values on different non-target organisms. This approach appears simple enough to apply at both farm and national levels and still takes into account the shift to new pesticides with low levels of active ingredient. The complex relationship between pesticide characteristics (toxicity, persistence and mobility) and the many different types of environmental impact they can have makes it impossible to rank pesticides unambiguously and there is no general consensus in favour of any one system (OECD, 1997). The percentage of a farm not treated with pesticides is also an easy indicator to use at an aggregated level.

The indicator of nature or landscape values measured in terms of the percentage of farmland made up of small biotopes is also used at a regional level in Denmark (Agger and Brandt, 1986) and similar indicators have been proposed in other European countries (Vereijken, 1994). This structural indicator, however, provides little information on the actual nature quality of farms (e.g. whether the flora in the biotopes has been reduced to nitrogen- or pesticide-tolerant species). Preliminary work therefore suggests the use of other indicators, such as the abundance of certain butterflies or sensitive wild plants. An attempt will be made to co-ordinate this work with that of a new project establishing indicators of nature quality for ultimate use at a national level.

Useful indicators not included in the farmer decision aid

The selection of indicators rests on value judgements, either implicit or explicit, concerning the relevant problems or criteria for success. An appropriate set of indicators, will therefore depend upon the geographical site under analysis and the level of decision-making for which the indicator is intended.

The selection of indicators presented in this paper is appropriate to Danish conditions, although most of the issues addressed are probably also relevant to other European regions with high intensity livestock farming. Nevertheless some indicators may be lacking due to the speical conditions in Denmark. For example, water use is not a problem in Jutland, where milk production is located, although it could easily be included as an indicator if necessary. Water use might be an interesting indicator to use from a National or European perspective and could be defined as tonnes of water used per tonne of milk, grain or meat produced. Another example is that of topographically induced erosion, currently regarded as only a minor problem in Denmark, but of relevance to other regions of Europe.

As argued by de Wit *et al*. (1995) the choice of sustainability indicators must be based on explicit issues of non-sustainability and issues of general interest. Some of the issues often included in discussions on sustainability are simply not relevant at a farm level (Kristensen and Halberg, 1997), whereas at a political level the discussion is far more wide-ranging and more indicators need to be identified to address new and relevant issues.

The use of land for different purposes (recreation, industry, urbanisation and agriculture) is of interest to society as land is a limited resource. The amount of farmland needed to produce a given agricultural output, using different production methods, is therefore, also interesting to politicians. Refsgaard *et al.*, (1997) shows, for example, how the lower energy input needed to produce one kg of milk on organic dairy farms is associated with a lower milk production per ha, with the result that more land is needed in order to produce the same amount of milk as conventional farms. This point might be taken further by also calculating the indirect demand on land through the feed imported for milk and meat production. Danish milk and pork production is a good example using large amounts of soya beans and sunflower cakes imported from, among others, Argentina.

Another normative assumption behind the definition of relevant indicators is linked to the question of responsibility. In our work it was assumed that in working with indicators at an individual farm level, there was little point in measuring effects that are simply the consequence of a given level of production. Therefore, CH_4 or N_2O emissions were not included as this is something, over which, the farmer has little influence, assuming a certain level of production[2]. A dairy farmer could, of course, reduce his milk output and thereby reduce the loss of CH_4 or N_2O, which are major contributors to the increasing green house effect (Duxbury *et al*., 1993). However, given the existence of EU milk quotas it is reasonable to assume that a reduction in production on one farm would be compensated for by an increase on another. The same argument applies to other commodities, where the individual farmer has little influence over consumer demands. However, this is not necessarily true at a national, EU or global level. The effect that total agricultural production has on the atmosphere is of great interest and indicators for the loss of CH_4 or N_2O, together with CO_2, should be included within a global set of environmental indicators (OECD, 1997).

Filling in data for farm and regional level indicators

Although most of the indicators identified for the ethical account are also of interest to policy-makers, this different perspective and level of focus does demand some modification of the indicators to ensure representative data and to cover issues neglected in the farmers' decision aid. The variation in Danish livestock farms alone, highlights some of the difficulties involved in the establishment of standard values for the potential environmental impact of ”typical intensive livestock farming systems”. These difficulties are compounded when intensive livestock farms in different European countries. Neither the method for establishing models of typical farms or a set of statistically representative farm data from different regions will be dealt with here**.**

Another possible approach is to focus on regional or national input/output statistics for agriculture, divided according to sector. One example of this is the agricultural phosphorus balance for European countries developed by Sibbesen and Runge-Metzger (1995), other examples are given by OECD (1997). Although such statistics are important in determining the level of resource use and environmental impact of agriculture in a given country or region, this type of information is, in itself, unlikely to provide a sufficient basis on which to make policy. The large variation in farms cannot be addressed satisfactorily by concentrating on regional or national level data alone. It is also impossible to understand fully the need for tighter regulation of intensive livestock farming or the consequences of different policies without first understanding how typical livestock farmers adapt to changes by altering their production methods. For these reasons it is a combination of regional agricultural statistics and models of different livestock farming systems which might ultimately facilitate appraisal of the potential environmental impacts of livestock policies in the EU.

This again points to the need for quantitative farm level indicators defined in the same way as more aggregate level indicators. The “driving force – state – response” concept presented by OECD

[2] Using new technology it might be possible to capture some of the methane lost from slurry tanks. Recent evidence also shows that the loss of nitrous oxides from the soil partly depends on the soil structure, which farmers are able to influence. It goes without saying that in cases where new technology/knowledge gives farmers the opportunity to improve their efficiency, it is appropriate to introduce a new indicator into the management tool/environmental account**.**

(1997) provides a good framework within which to establish a comprehensive definition of indicators for use at different levels. In this way the farm-level state indicators presented here could be used as driving-force indicators at a regional level thereby giving a more coherent description of the link between activities on individual farms and their potential environmental impact on the surrounding area. An important step forward would therefore be to establish a set of intensive European livestock farm types, which could be described using the indicators mentioned above and, for example, also the concept of farming styles (van der Ploeg, 1993; 1996) to characterise the intra- and inter-regional variation.

Conclusion

A set of simple indicators describing the resource use and environmental impact of intensive livestock farms as they relate to the relevant interests in society have been presented. The indicators of N, P and Cu surpluses per ha, energy and water use per unit of production, average FTI of pesticides, percentage of farm land untreated with pesticides and the percentage of farm land under different crops and or made up of small biotopes are all applicable at farm level as well as aggregated levels (region, country etc.) and describe important differences between farming systems. These indicators summarise the results of several actions on a farm over a given period and thus are state indicators at the decision level of the individual farm. At higher decision levels the same results might be conceived as driving forces having impact on the state of ecosystems and natural resources both inside and outside the agricultural systems. The establishment of a set of results from typical European livestock farms and a comparable set of aggregated data might facilitate a better discussion of the needs for and consequences of different types of regulation.

References

Agger, P. and Brandt, J., 1986. Udviklingen i agerlandets småbiotoper i Østdanmark. Forsknings-rapport nr. 48 Roskilde Universitetscenter. p. 541.

Bawden, R.J., 1992. Systems Approaches to Agricultural Development: the Hawkesbury Experience. Agricultural Systems. Elsevier Science Publisher Ltd., England. pp.153-176.

Bååth, E., 1989: Effects of heavy metals on soil microbial processes and populations (a review). Water, Air and Soil Pollution 47, 335-379.

Christensen, N., Paaby, H. and Holten-Andersen, J., 1993. Miljø og samfund - en status over miljø-tilstanden i Danmark (State of the environment in Denmark). Faglig rapport fra DMU nr. 93. p.160.

de Wit, J., Oldenbroek, J.K., van Keulen, H. and Zwart, D., 1995. Criteria for sustainable livestock production: a proposal for implementation. Agriculture, Ecosystems and Environment 53, 219-229.

Doluschitz, R., H. Welck and Zeddies J., 1992: Nitrogen balances at farm level –a first step towards an ecological bookkeeping system. Berichte über landwirtschaft 70, 551-565.

Doran, J.W. and Parkin, T.B., 1994. Defining and assessing soil quality. In: Doran, J.W., Colemann, D.C., Bezdicek, D.F and Harris, R.F. (eds). Defining Soil Quality for a Sustainable Environment. Soil Science Society of America, Inc. (SSSA) Special Publication Number 35. pp.3-22.

Duxbury, J.M., Harper, L.A. and Mosier, A.R., 1993. Contributions of Agroecosystems to global climate change. In Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Special Publication 55, 1-18.

Fluck, R.C. and Baird, C.D., 1980. Agricultural Energetics. AVI Connecticut. pp 41-71.

Forman, R.T.T., 1995. Land Mosaics. The ecology of landscapes and regions. Cambridge University Press, Chapter 5. Corridors. pp.146-176.

Garlynd M.J., Karakov A.V., Romig D.E. and Harris R.F. 1992. Descriptive and Analytical Characterisation of Soil Quality/Health. In Doran J.W., Colemann D.C., Bezdicek D. F. and Harris R.F. (eds.).Defining soil quality for a sustainable environment. Soil Science Society of America, Inc. (SSSA) Speical Publication 35. 159-168.

Girardin, Ph. and Bockstaller, C., 1994. Evaluation agri-environnementale des exploitations agricoles au moyen d'indices agro-écologiques. INRA, COLMAR. p.9 .

Halberg, N., Kristensen, E. Steen and Kristensen, Sillebak I., 1995. Nitrogen turnover on organic and conventional mixed farms. *J. Agric. Env. Ethics.* 8, 30-51.

Halberg, N., 1997. Farm level evaluation of resource use and environmental impact. In: Isaart, J. and Llerena J.J.,(eds): Proceedings of the 3th ENOF Workshop, ”Resource Use in Organic Farming”, Ancona.

Halberg, N., 1998: Researching farmers possibilities and motivation for including environmental aspects in their management. Paper for 3rd AFSRE symposium, Rural and farming systems analyses:Environmental perspectives. Hohenheim, March, 1998.

Halberg, N. and Jensen C.H., 1996. Dairy farm production strategy and nitrogen surplus. In: Walter-Jørgensen. A. & S. Pilegaard (eds). Integrated environmental and economic analyses in agriculture. Statens Jordbrugs- og Fiskeriøkonomiske Institut. Rapp. 89, 103-120.

Halberg, N. and Jensen K.K., in prep: Indicators of resource use and environmental impact to be used in an ethical account for livestock farms.

Harrington, L.W., 1992. Measuring Sustainability: Issues and Alternatives. Journal for Farming Systems Research-Extension, 3, 1-20.

Huysman, F., W. Verstraete and Bruce, P.C., 1994. Effect of manuring practices and increased copper concentrations on soil microbial populations. Soil biol. Biochem 26, 103-110.

Håkonsson, I. and Reeder, C., 1994. Subsoil compaction by vehicles with high axle load-extent, persistence and crop response. Soil and Tillage Research 29, 277-304.

Jensen, K.K. and Sørensen, J.J., 1997. The idea of an ethical account for livestock farms (submitted).

Karlen, D.L., Erbach, D.C., Kaspar, T.C., Colvin, T.S., Berry, E.C. and Timmons, D.R., 1990. Soil Tilth: A Review of Past Perceptions and Future Needs. Soil Sci. Soc. Am.J 54, 153-161.

Korevaar, H., 1992: The nitrogen balance on intensive Dutch dairy farms: a review. Livestock Production science 31, 17-27.

Kristensen, Steen, E. and Halberg, N., 1997. A systems approach for assessing sustainability in livestock farms. In: Sørensen, J. Tind et al. (Eds): Proceedings of the 4th International Livestock Farming Systems Symposium, More than food production. Foulum, 1996.

LEAF, 1993., Farm audits: Linking environment and farming. Integrated crop management. NAC, Stoneleigh, UK.

Larsen, M.M., Bak, J. and Scott-Fordsmand, J., 1996. Monitering af tungmetaller i danske dyrknings- og naturjorder. Prøveudtagninger 1992/93. (Monitoring of heavy metals in Danish soils). Faglig rapport nr. 157 fra Danmarks Miljøundersøgelser. pp 77. With summary in english.

Mayrhofer P. and Schawerda P., 1991. Die Bauern, die Natur und das Geld. Modell Ökopunkte Landwirtschaft. Verein sur Förderung der Landentwicklung und Intakter Lebensräume, Baden, Østrig. Pp.117

McLaughlin, A. and Mineau, P., 1995. The impact of agricultural practices on biodiversity. Agriculture, Ecosystems And Environment 55, 210-212.

Nitsch, U., 1990. Computers and the nature of farm management. Knowledge in Society. The International Journal of knowledge transfer, 3, 67-75.

Nocquet, J., 1995. Gestion de l'espace et maîtrise des risques de pollution. Une méthode de diagnostic environnemental d'exploitations d'élevage. Ann Zootech 44, Suppl. 338.

Noe, E., 1995. Value orientation and styles of farming. A study of thirty-one Danish organic and conventional livestock farmers. Working paper. Danish Institute of Agricultural Sciences, Department of Production systems.

OECD, 1997: Environmental Indicators for Agriculture. p.62 .

Pimentel, D. *et al*., 1973: Food production and the energy crisis. Science 182, 443-449.

Prip, C., Wing, P. and Jørgensen, H. 1995. Biologisk mangfoldighed i Danmark - status og strategi. (Biological diversity in Denmark). Miljø-og Energiministeriet, Skov- og Naturstyrelsen. p. 200.

Reddersen, J., 1998. The arthropod fauna of organic versus conventional cereal fields in Denmark. Biological Agriculture and Horticulture. In press

Refsgaard, K. , Halberg, N. and Steen Kristensen, E., 1998. Energy utilisation in crop production on organic and conventional livestock farms. Agricultural Systems. In press.

Riemsdijk, W.H. van, Lexmond, Th.M., Enfield, C.G. and van der Zee, S., 1987. Phosporus and heavy metals: accumulation and consequences. H.G. van der Meer et al. (eds). Animal Manure on Grassland and Fodder Crops. pp.213-227.

Schjønning, P., Sibbesen, E., Hansen, A.C., Hasholt, B., Heidmann, T., Madsen, M.B. and Nielsen, J.D., 1995. Surface runoff, erosion and loss of phosporus at two agricultural soils in Denmark - plot studies 1989-92. SP report no. 14. Danish Institute of Plant and Souil Science. p. 196.

Schroll, H., 1994. Energy-flow and ecological sustainability in Danish agriculture. Agriculture, Ecosystems and Environment, 51. pp.301-310

Secher, B.J.M and Gyldenkærne, S., 1996. Regulating pesticide use and environmental impacts: In: Walther-Jørgensen, A. and S. Pilegaard (eds) Integrated environmental and economic analyses inagriculture. SJFI,Copenhagen, report 89, pp.163-172.

Sibbesen, E. and Runge-Metzger, A., 1995. Phosphorus balance in European agriculture - status and policy options. In H. Tiessen (ed.): Phosphorus in the global environment. SCOPE no. 54., Wiley. pp. 43-57.

Tiessen, H.,1995. Phosphorus in the global environment. SCOPE no. 54., Wiley.

Van der Ploeg, J.D., 1993: Rural sociology and the new agrarian question. Sociologia Ruralis 33, 240-260.

Van der Ploeg, J.D., 1996. Bottom up pressures on intensive livestock systems. In: Proceedings of the third international symposium on livestock farming systems Eds. . EAAP publication No. 79, pp.37-49

Vereijken, P., 1994. Designing Prototypes. Progress Report 1. Research Network for EU and Associated countries on Integrated and Ecological Arable Farming Systems. p. 87.

Wijnands, F.G., 1997: Integrated crop protection and environment exposure to pesticides. Eur. J. Agron. 7, 251-260.